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VIEWS

OF

ASTRONOMY.

SEVEN LECTURES

DELIVERED BEFORE THE MERCANTILE LIBRARY ASSOCIATION OF NEW YORK IN THE MONTHS OF JANUARY AND FEBRUARY, 1848.

BY

J. P. NICHOL, LL.D.

PROFESSOR OF ASTRONOMY IN THE UNIVERSITY OF GLASGOW.

REPORTED FOR THE NEW-YORK TRIBUNE
BY OLIVER DYER, PHONOGRAPHIC WRITER.

NEW-YORK:
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1848.

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INTRODUCTORY.

THE following Lectures were delivered in this City in the months of January and February of the present year. They were received with the highest satisfaction by a crowded and most respectable audience, who, at the close, passed a unanimous vote of thanks to their distinguished author. Having been regularly reported verbatim in *The Tribune* by that well-known Phonographic Reporter, Mr. OLIVER DYER, a very general wish has been expressed for their publication in a form more suitable for preservation, in compliance with which the present collection of them is laid before the public.

Those into whose hands they may fall as the first specimens of the glowing and eloquent yet lucid manner in which Dr. NICHOLL sets forth the sublimest laws and grandest generalizations of Astronomy, will naturally desire to know something of the man who thus brings matters more more commonly locked up in dry, scientific formulas within the reach of the popular apprehension. The life of Dr. N. without being marked by any extraordinary incidents, is yet deeply interesting as an illustration of the success with which talent and perseverance can make their way against opposing circumstances. Born in 1809, in an obscure village in the south of Scotland, he is indebted solely to his own efforts for the position he now holds. He is in every way a self-made man, and has the advantage of a wide practical experience in various conditions of life. Devoted from the first to scientific studies, he has discharged successively the duties of a teacher in all the grades of that employment. He has now for some years been Professor of Astronomy in the University of Glasgow, in which situation he has gained his present elevated general reputation.

The present visit of Dr. NICHOL to this country is undertaken in compliance with a long-cherished desire. He has leave of absence from his official duties for the period of one year, during which he proposes to visit our leading cities, and if his experience in Boston and New-York be a test, will scarcely be allowed to pass through any of them without being called to address the public in lectures on his favorite Science.

As a popular speaker Dr. N. is peculiarly gifted. To an exterior and manner which win the attention of his audience, he unites a style of speech at once chaste and impassioned, as eloquent and finished as it is rich and glowing. When treating of the more magnificent branches of Astronomical Science, his periods seem to rise and and roll forth with something of the luminous grandeur which is characteristic of their subjects. There are passages in the following Lectures, and in others of his productions, which are scarcely surpassed in literature.

Perhaps the greatest and most permanent distinction to which Prof. NICHOL is entitled is that of rendering the great truths connected with the structure of the heavens acceptable to the public at large. In this he has conferred a greater benefit on the world than could be done by the discovery of a new Comet, or the resolution of any merely theoretical problem. Until recently these truths were a sealed book save to the learned few; now they are the common property of all, expanding the minds, elevating the hearts and kindling the imaginations and the religious sensibilities of thousands to whom they might else have remained unknown for ever. It was this which gave to Dr. LARDNER'S Lectures on kindred subjects their extensive and continued popularity. Prof. N.'s writings have been republished in this country, and with the labors of our own MITCHEL, who has followed in the same path, have had an extensively beneficial influence.

Perhaps the best known in America of the works of Dr. NICHOL is his "Views of the Architecture of the Heavens." This has been very widely read and admired. It sums up the great discoveries of Herschel and Laplace in a most worthy and successful manner, and is generally regarded by its readers

as a sublime and even an overwhelming book. Indeed, we know of no work of its size which presents such a mass of stupendous facts and principles. It carries the reader into the inconceivable domains of infinite space, where the thick universes are sown like dust in the sunbeam, and humbles while it excites the mind with the grandest displays of Omnipotent Wisdom and Power.

We believe that the readers of these Lectures will find in them abundant evidence of the same brilliant genius; at least such confidence is justified by the testimony of all who heard them delivered. We annex a list of the published works of Dr. NICHOL:

I..“Views of the Architecture of the Heavens.” II..Contemplations of the Solar System. III..Thoughts on Important Points connected with the System of the World. IV..On the Planet Neptune. V..On the Stellar Universe. VI..A Treatise with Preliminary Description and Notice of “Willson on the Education of the People.”

ASTRONOMY.

LECTURE I.

Means of Penetrating into Space, and Examining Remote Objects....Estimate of the Powers of the Telescope....General Aspect of the Starry Heavens....Questions as to the Significance and Extent of our Vast Firmament....The Milky Way....Limits of our Great System....Discovery of External Clusters or Masses of stars, each of which is to the individuals composing it, their own peculiar heavens....Extent and Magnificence of the Material Creation—Its Infinite Variety....Concluding Reflections.

This distinguished Astronomer was greeted on the evening of January 25 by a large and highly intelligent audience, who manifested the deepest interest throughout his Lecture. He spoke as follows:

LADIES AND GENTLEMEN: Already I have learned enough of America to know how needless it is that a visiter from Great Britain should begin an intercourse such as I propose to establish here with anything merely apologetic, for I believe that, these two nations resting on the opposite sides of the Atlantic, in whatever discussion of minor interests we may be severed, we are still neither of us inclined to forego the privilege derived from our common language, and also a common, and surely I may say an illustrious ancestry, of union in the grand task of exploring through the mazes of creation the mighty ordinances of God, and of contemplating together, for a moment. the deeds of those who have striven to unfold them. Confident, then, of an entirely kindly reception—confident that I may almost drop the name of a stranger, I would now venture to bring before you some of those contemplations which are pressed upon us by a consideration of the laws which govern the great Universe in which we are. I would venture that we cast our eyes for a while upward from the Earth, toward that dazzling array of stars which, bursting forth as the luminary of day declines, summons us to the contemplation of those vast infinitudes in which they are.

It is my wish, during the present Lecture, to pass with you upward from these confines of our Solar System, toward that grand congeries of orbs of which our Sun is the center, and to trace among these, if we can, marks of that order and system which indicate to us, as do all the phenomena around us, that we are here amid an Intelligence which preserves them even as at first created It is not certainly unnatural when one considers the depths at which these stars lie, the impassable character of the gulfs which separate them from our Earth, that even at the threshold of the inquiry, we should be met by an unbelief in many respects, whether or not we can reach them, or, at all events, be able to carry there a precision of view, without which no permanence of understanding regarding their arrangements can well be discerned. On which account permit me, in the first place, briefly to place before you the principle on which these great instruments have obtained the power to which we owe our knowledge of these remote realms of Space. I would for one moment, ladies and gentlemen, previous to entering upon the subject, request your attention to the character of that great telescopic power which has enabled us to pierce beyond the confines of our own system, and examine those mighty orbs which fill the boundless realms of Space beyond it. The telescope is not a simple instrument; but when we look at it with regard to its more simple elements we see at once, and clearly, how it enables us to go into these great profundities. We find that when one views with the naked eye a distant object, the power of vision is dependent on one plain and very distinct circumstance. It is this. We find that the power of vision cannot be made sensible, unless the light that comes to the eye from the object viewed is of a certain distinct quantity or density. There can be little doubt that, however far away the brilliant object is, if it is sending forth light through all space, that light must reach every nerve which is capable of receiving it; but still, unless it reaches the human eye with a sufficient power, density or intensity, it will not enable that eye to have the sensation of sight or vision.

Suppose, for instance, we have a brilliant point A, as thus: A B C sending out light through all Space; wherever an eye is placed capable of receiving light from that brilliant point, it must inevitably receive rays from that point; in other words, it must be acted upon by that point so as to receive the sensation of vision. It is so with regard to the human eye. Unless a certain density of light enters it, the sensation of vision will not be preserved. Notwithstanding what the distance of the object may be, light must enter into the eye from that object. Suppose, for instance, the eye is placed at C: the light coming from the object A, being dispersed through space, will necessarily be less than the light at B, and, while the light at B is a definite, distinct quantity, the light received by an eye at C may not be at all sufficient to operate upon the nerve, so as to cause the perception of vision. Now then, supposing that when the eye at C is presented to the brilliant point A, that that point is merely sending forth a quantity of light sufficient to cause the sensation of light and nothing more, what would we require to do in order to make this point or star brighter than it naturally is? It seems to me we would require to make the light coming from this star more dense than it appears to be when in its natural state. Now, the point is, how can this be done? How can we, by means of any art or science, place the eye in such a relation to the star, that it shall view a greater quantity of light than it

naturally does? There is a principle in optics which comes to our aid, of a very plain and distinct kind, and which I think the audience will at once understand. Suppose that we place at B a lens, a piece of glass so shaped that when the rays of light pass from the star or the brilliant object A, through it, they shall no longer preserve their rectilinear course, but shall be caused by the lens to converge and fall upon the eye at C. The audience will at one perceive that the eye at C is altogether in a new position. Instead of receiving merely a faint, dim ray of light, it is now receiving a great, clear and strong ray of light, formed by the concentration by the lens of the numerous rays of light, which previously were diffused over a large surface. This is the principle upon which the telescope acts. It collects the scattered rays of light, and causes them to fall upon the eye in the manner of the lens, as just described. Let us see, then, what must be the power of the telescope, as compared with that of the eye. It is simply this: If we have placed between the eye and an external object, any great lens, we will see that object with an amount of light, just as much greater as the lens through which we are viewing it is greater than the pupil of the eye. Now, it seems to me that, if we understand this very simple principle, the great power of the telescope can be easily and at once ascertained. Suppose, then, we refer back to the telescope of Galileo—that little, simple telescope with which he first attempted to make his way in the heavens. We find that it is but a little more than an inch in diameter. Yet still, when we compare the surface of light which that inch necessarily met, with the quantity of light falling from any object upon the pupil of our eye, one cannot at all marvel that we should be able to see through comparatively small glasses, objects situated at great distances with very remarkable distinctness.

Until comparatively recently, the telescope had not at all reached the great power which it now possesses. The instrument recently used by us, was perhaps one whose object glass, or mirror, was not larger than eighteen inches in diameter. This was the one by which Sir William Herschel was enabled to make his grand discoveries. Recently, however, we have constructed instruments of much greater power. The vast telescopes of Lord Rosse have reached the diameter of four and even six feet. Now, if the audience will for a moment consider the immense surface of a mirror of six feet in diameter, compared with the surface of the pupil of the eye, I think that it will not be at all marvellous to them that the power of these telescopes should be so enormous as has been reported. The telescopes of Herschel, which were about eighteen inches in diameter, possessed ninety-five times greater power of penetrating into Space than the naked eye; but the power of the telescope of Lord Rosse—the greatest one that has recently been introduced—seems to be something less than five hundred times that of the naked eye. Now, this immense space-penetrating power may be approximately realized, by referring for a moment to the great velocity with which light passes through space, which is about 200,000 miles per second. Now, it seems that Lord Rosse's telescope has the power of penetrating through space so far that the most distant star which it can reach is at such a vast distance from us, that its light, moving with this almost inconceivable velocity, cannot reach us in less than 60,000 years.

It is not, however, merely in regard to their powers as light-graspers, that the efficacy of these telescopes mainly depend. Let this power be ever so great, little advantage is gained unless there be perfect accuracy of image. The great advantage of Lord Rosse's telescope depends not solely upon its power of penetrating into Space, but also upon the accuracy with which it gives us the image of the object viewed through it. It is in these respects that that mighty instrument has achieved its greatest exploits. When the greatest magnifying power is applied, it shows not the slightest amount of distortion in the object. It is not possible to render the astonishing accuracy of Lord Rosse's telescope fully palpable. There is a minute point near Polinarius, *so* minute that it requires a good telescope at all to discern it. Now, with the very high magnifying power of Lord Rosse's telescope, I have seen that point, as clear, as distinct as a star of the first magnitude. With such powers in our possession, then, let us proceed reverentially, but still without dread, to scan those truths to which they have enabled us to ascend. When regarding the constitution of the Stellar Heavens, it is not unlikely that again we may be stopped by incredulity. According to our usual ideas, these starry heavens seem infinite. They appear as if they occupy all Space, filling with crowds of constellations wherever the human mind can fancy that Space is open to receive them: and, therefore, it would seem that although our augmenting telescopic power might bring us augmented knowledge, we are yet contending with what is hopeless. Now, as the removal of this popular fallacy lies at the root of all our modern views of the structure of the heavens, I must solicit for it your attention.

Even after we have ascertained how far the telescope is able to pierce, it may yet come back to us as a cause of doubtfulness, whether we can get a rational conception of how the Stellar Heavens are constituted. Is it not likely that these heavens which we see around us and over us, penetrating infinitely into space, present to the eye nothing different from what we see here? Suppose this question occurs to us, shall we be able to ascertain aught concerning the structure of these great heavens? Now it seems to us at first, perhaps, that this is a perfectly legitimate objection to our moving farther with our inquiry. It may be said, that when we observe the skies on a clear night, we have before us all that can be seen. Now this grand conception, namely, that if we were passing throughout space we should simply meet nothing else than what we see around us—just constellation after constellation as we went onward through these depths of infinitude—I say that this conception is so very natural that it is difficult for us to conceive that it is not true. However, on a slight consideration I think that we will be able to see that this is not what our heavens really indicate to us. If what I said were true—if the stars extend on through our skies toward infinitude, if as we went along—supposing we had it in our power—throughout these clusters we should see nothing but constellations after constellations, I think that our heavens would not appear to us as they do now. Suppose for instance we had reached far away beyond these constellations what would we see behind us? We would see the great, brilliant stars of the first magnitude, then we would see behind these, those of the second magnitude, behind these again those of the third magnitude and so on; but we would find always in every part of our sky when we reached that position where we could see no more stars, a sort of background—a dim diffused light called nebulous light. If that were the constitution of our skies this would be their appearance. You would find lying backward through the whole path of the sky this dim milky light. On the contrary, we see it only

on one side of the heavens in that great range called the Milky Way. Now the question is, what is the cause of this? Why do we find this great milky belt, so to speak, passing over our sky in one direction and not in another? It seems to me that if we look at this question calmly this conclusion must necessarily occur to us, namely: that in that part of the sky alone, where we see the Milky Way is there a bed of stars diffused throughout the unfathomable depths of space. If it were otherwise, if this bed of stars was found to be diffused throughout all regions of the heavens, then, certainly, that peculiar appearance that stikes us as we look at the Milky Way would be found as the background of all the heavens. In every range we would see the stars of the first, second, third and fourth magnitudes; then, when we arrived at that part of the heavens where we could not distinctly trace the individual stars, we would find a background filled with this dim, milky light.

It seems then that our first notion, namely, that these stars stretch away throughout space is not a true one—that this Milky Way manifests to us a peculiar structure. Now the question is, what is that structure? how can we ascertain what that structure is? Belonging to the great bed of stars in the midst of which we are, we find, on looking at the heavens, that stars of the first, second and third magnitude are tolerably equally scattered throughout all space. It is only when we come to stars of the very smallest magnitude that we find a derangement of this distribution. What does this indicate to us? It seems to indicate the following, namely: that as far as the naked eye can reach, these stars, on to the very smallest magnitude, are pretty equally scattered throughout our skies; but that if we get beyond their region, peculiarities of constitution come into view, and we begin distinctly to see that we do not belong to a universal, but to a certain, definite and distinct class or mass of orbs with which we are connected—a mass of orbs with boundaries almost inconceivable, but still a definite and distinct mass.

The idea that I have thrown out may yet be pushed a little farther. It may be shown that if these stars were diffused through all space, our heavens would on every side blaze with a splendor so bright that the Sun would not be visible to us at noonday. It is clear, then, that such cannot be the characteristic of our skies. It cannot be that these orbs we are discerning are spread infinitely throughout space, but, on the contrary, in all likelihood they are forming a great cluster or bed of stars of a peculiar and distinct shape. These thoughts which I have just laid before you were first seized by the illustrious Sir William Herschel, and although his conclusions cannot be placed before you as infallible, yet his first ideas lead us in our first progress toward a view of the heavens. Herschel's first conception with reference to the nature of the heavens was the following. He said, "It is clear that this great multitude of fixed stars is not what it was formerly supposed—the *infinite* heavens.—This great mass of stars is simply a vast cluster or congeries, and nothing more." When this great idea had dawned upon him, he asked, "Is it possible to ascertain what is the description, the general character, of that vast bed of orbs in the midst of which we are?" The notion was certainly a very great and marvelous one, but still he was enabled to come to a conclusion not very far, I believe, from what we now think to be the true one. The idea upon which he worked was the following: He said, "Suppose that this room is filled with persons, and that they are pretty equally dispersed over it. Now suppose that I turn my eyes in a certain direction and count the number of persons that I see before me, and then direct my eyes to another part of the room and again count the number of individuals that meet my gaze: then, being certain that these persons were pretty equally scattered throughout the room, I would be enabled to infer from the number of persons located in the sections of the room to which I had directed my investigations, how far I must be from the edge of the room in this or that direction." This was Herschel's idea, and he turned his great telescope in every direction round the heavens, judging how many stars he saw in every place, and he found in this manner how far he supposed he was from every portion of the edge of the cluster. The mode in which he attempted to make out a scheme of the character of the heavens was this.

[The lecturer here drew a diagram upon the black-board resembling a luminous body from which rays of light emanated in every direction—the rays varying in extent in such a manner as to form a sort of elongated spheroid indented at the edges.]

Suppose this (pointing to the luminous body) is the Sun, and these lines (pointing to the rays) indicate the directions in which his telescope was turned, and their lengths indicate the number of stars he observed. Well, he turned his telescope all round through our heavens and drawing a sketch of this kind, he then joined the edges of these different lines, making a figure like this. And he said "this, in all likelihood, is something of the shape of the great cluster of stars in which we are."—His idea, perhaps, is better represented thus. Let the audience in imagination follow me. Suppose we had it in our power to move up through the Milky Way and pass along through that congeries of stars till we lose our connection with the Siderial system. The following phenomena would be observed: We should pass on from our present congeries, still moving, as it were, amid an infinite number of orbs, till, by-and-by, we should have no stars in advance of us and the only systems would be behind us. Suppose we should go still farther out amid these awful recesses till this vast scheme of ours would take on gradually and gradually the shape of a mere speck lying against the dim of the far heavens. Such would be the general aspect of that mass of stars with which we are in immediate connection. [Applause.]

The investigation which led Herschel to the conception that this was the scheme of our heavens, was the following—and you will perceive at once that it was subject to two great errors: On trying to find out a view of the skies, he had the conception constantly in his mind, that the stars were pretty equally scattered through all space. Now, to return to my illustration: suppose that I were to count the persons in different directions around the room, and inferring from that how far I was from all sides of the room, I would necessarily rest upon the conviction that the people were equally scattered throughout the room. So Herschel said that the great mass of stars throughout the heavens were pretty equally distributed. Now, since his time it has been ascertained that this is not true. It has been found that all around us, so far from the stars being pretty equally scattered, they are, quite on the contrary, thin, as if in a desert. Herschel was, therefore, wrong in his opinion of the scattered condition of the orbs around us. There was another thing in which he was erroneous. You will observe that when looking all around in the sky, he could never have supposed that he was entitled to draw the conclusion with respect to the depths of the orbs in any direction, unless he knew, or had reason to believe, that his telescope enabled him to go to the end, or at least nearly to the end, of our system in that direction. Suppose, again, that I was here counting the

number of persons that I see in any direction—unless I was sure that I had arrived at the end of the room, it is plain that my counting would be of no value as far as certainty is concerned. This was also another of Herschel's views, the inaccuracy of which has been fully proved. He found, and we find now, that not the largest telescope has ever been able to pierce to the extremity of our system. Perhaps the best inference we can draw is the following: We are not speaking of the Solar System, but of that vast system of orbs that you see on a clear night beaming across the heavens. Well then, the question as to what our System is, is probably better explained by our looking at external objects than it can be by our viewing the aspect of what lies quite within it. For instance, this is one immense cluster lying perfectly apart from our System.

[The lecturer here pointed to a chart, on which was represented a brilliant cluster of stars composed of three rings, one within the other, the most brilliant being in the center.]

We find this when the power of the telescope is fully applied, to present an appearance like that on the chart. How far this cluster is removed from us, it is utterly impossible to tell. Its appearance, however is not very unlike what that of our system might be, if it were viewed from this distance. If we consider for a moment this statement, it will not appear improbable. The milky-way is a great ring extending in two ranges through our heavens, so that it may be that our system is an immense ring similar to this cluster. If this idea is realized another immediately suggests itself, and which Herschel also early recognized. Vast as our firmament may be, has it boundaries, or does it stretch away into infinitude? Are those awful spaces that surround it on every side void, empty, or are they tenanted by worlds and systems similar to our own? No wonder that a mind like Herschell's should have rushed to the conclusion that the space around our system was a vault in whose capacious bosom myriads of mighty clusters like our own universe are placed. If it be true that this great scheme of ours is simply that which Herschell first supposed it, but still a great, *separate, distinct* scheme, whose nature is, perhaps, more than anything else, represented by these singular Nebulae, what must we think with regard to it? Surely it is that, notwithstanding its immense diffusion, its vast confines, the great space through which its different portions range, there must lie around it on every side, vast untenanted spaces, and if this be so may it not be that amid all that space also, there are floating great schemes of being like ours, schemes I say of different shape, of different character, but lying in these vast regions of space like ours, schemes quite as magnificent as that vast system to which we ourselves belong. If this is so what a conception in regard to the material universe, must press itself upon our notice.

It seems to me the conception must be just like that which a dweller upon an island in the great Southern Ocean, who had never passed beyond the limits of the little world in which he lived would experience, if to him were brought information that what he considered his world was but a diminutive island, and that around him in this Ocean lay scattered large groups of islands and vast continents.—Such is the information with respect to the Stellar Universe that has been conveyed to us by the powers of our great telescopes. [Applause.]

The great inquiry is this: What is the character of these immense groups; what their form; what the nature of the shapes in which we find them collected; and what the destiny through which they are doomed to pass? Now in the first place we find that these groups are for the most part approaching to circular—I should hardly use the word circular, but spherical. Now that this is not altogether true; that we do not find them altogether spherical may possibly be represented to you by merely looking at one mass of these elements. [The lecturer here exhibited another diagram, representing a nebulous group, of a nearly circular form.] This mass is something like what by far the greatest number of these different groups are; but when our greatest telescopes are brought to bear to upon them. we find that those which which were thought to be spherical are not so; they approach nearer to a globe. Here is one which looked oval, but Lord Ross's telescope brought it into a circle.—Lord Ross called it the crab nebula, because it resembles a crab.

Now, there occurs a very remarkable circumstance in reference to these comparalively sweeping circular masses of nebulæ. We find they are not entirely circular, but the reverse, and that all around them, on every side, there are volumes of stars stretching out apparently as if they were rushing toward a grest central mass in consequence of the action of some great power—the power of gravitation. We find them approaching to spheres, and around their spheres we find these volumes apparently tending toward a center, which ultimately may become the great central region.

If this is true—if the idea is correct] that great masses such as this, for instance, are in the mean time merely in a condition of change—that all these orbs are now forming their volumes with a view to become ultimately incorporated with it—how stupendous the idea! It takes our thoughts from the mere transitories of Earth, and places them on the august things of Eternity—it realizes, as closely as the material Universe can do to Man, the awful unchangeableness of that Being who has created these things, whose steps fill Eternity.—Passing from these remarkable spherical masses, on toward the irregular ones, we find that, although we cannot at all understand them as unities, yet there are clear and distinct manifestations of changes passing along them so great that we are obliged to look upon these changes as containing the secret of the remarkably capricious forms these orbs have. Suppose, for instance, we look upon this circular mass [pointing to a diagram] so far away that light cannot come to us from it in less than sixty thousand (60,000) years. If we look at this, it will be seen that it is almost impossible to reconcile its curious form with any shape.

Now, although we find it inexplicable when we look at it as a unit, yet when we examine its different parts we will see that there may have been—that there are proceeding there great processes which will ultimately have such an effect upon that singular mass of orbs as to turn it into a different position from what it now occupies, There is something very remarkable in the forms of these nebulæ. The audience may have looked with some attention to the Milky Way. If so they will have seen that it is not at all like a regular, distinct belt, of brilliancy, from which we could infer that there is a regular succession of great orbs stretching out behind it. Instead of being a regular belt it seems like a succession of groups or masses of stars. precisely like what we see represented in the diagram. Its appearance is so very remarkable that Sir Wm. Herschel said when he first saw it, that "it was breaking up, and that the intervals of space lying between the bright parts are like the wrinkles of age." He said that "after a lapse of ages this vast belt would disappear—that instead of being a separate dis-

tinct belt, it would be a mere succession of brilliant, separate orbs or clusters stretching out through the whole heavens, but perfectly distinct and separate." He even went so far as to say, in one of his great moods, that "this great breaking up of the Milky-Way looked to him like the movements of the vast Chronometers of the Universe; that there were passing onward the distinct movements of the mighty Hand which marks the progression of the material Universe." To speculations like these one can add no adequate illustration. They are clearly beyond any sphere to which our human machinery can ascend.

The process of change in these nebulæ being probably beyond the existence of the individual and the duration of the human race, the character of that change can never be evolved except by a close comparison of all the forms which it involves, which will engage the energies of all the observatories of the earth. This comparison must not be undertaken even for the gratification of an enlightened curiosity, but for the purpose of elucidating one of the greatest questions that ever occupied the attention of man. In this investigation your own great telescopes at Cambridge at Cincinnati and other places must assist, not, as I said before, for the gratification of curiosity, but with the view of having mapped down these great nebulous changes, that we may get at the law which governs the movements of these wondrous bodies.

Ladies and gentlemen: I have endeavored to give you some idea of the nature of the gorgeous Universe amid which every moment of our existence is passed. How strange that this Universe is only yet cognizable by one human sense! that the veil of the Sun's light entirely conceals its wonders from our view—that had the light of that Sun not been veiled by the curtain of night we had lived amid it and never have known of the existence of the Stellar Universe. May it not then be true that during midnight, when these infinite orbs appear to us from their unmeasured depths—may it not be true that through veils as thin we are withheld now from the consciousness of other Universes vast even as the world of stars! But in reference to an idea so lofty, let me use the language of a greatmind:

> Mysterious Night! when our first parent knew
> Thee by report divine, and heard thy name,
> Did he not tremble for this lovely frame,
> This glorious canopy of light and blue?
> Yet 'neath a curtain of translucent dew
> Bathed in the rays of the great setting flame,
> Hesperus and the hosts of Heaven came,
> And, lo! Creation widened in man's view.
> Who would have thought such darkness lay concealed
> Amid thy rays, O Sun! or who could find
> What fly and leaf and insect had revealed,
> That to such countless orbs thou mad'st us blind?
> Why do we then shun death with anxious strife?
> If Light can thus deceive, why may not Life?

The Lecturer resumed his seat amid the general applause of the audience.

LECTURE II.

The Mechanism of these grand Stellar Clusters....Our Heavens replete with Activity and Motion....The System of Double Stars....More complex Groups....Idea of a Universal Mechanism....The Motion of our Sun through Space....Idea of a Central Sun....The instability even of our grandest forms and collocations of Matter....Relation of Material Changes to the Will of GOD.

LADIES AND GENTLEMEN: I endeavored to explain in my last Lecture what lights have now reached us respecting the arrangement of the Stellar Universe. Upon examination we find that the brilliant orbs which compose this vast Universe, are not distributed with any apparent regularity through space, but are thrown together into single groups or clusters, a few of which have been analyzed by the telescope. The forms of some of these groups, as unfolded by the power of those mighty instruments, are certainly most strange, and, whether the inference be correct or not, they forcibly impress upon us the idea that we are looking at incompleteness—at a phenomenon whose entire completeness is not displayed in its existing form—which, in fact, belongs to some wide scheme, and which is not intelligible except as an intermediate step in the course of some great progression.

I attempted, in my previous Lecture, to lay before the audience those great lights which we have obtained with regard to the structure of our great Stellar Heavens—to show that instead of the Stars being distributed throughout all space, our Heavens are but a simple cluster, a group,—a limited, definite and peculiarly shaped group. The nearest approach to the shape of this group may be found in the diagram before you. [Here the lecturer pointed to a large diagram representing an immense spherical cluster of stars, with the sun in the center,—the stars as they receded from the sun growing more and more irregular in their distribution.]

In connection with this cluster, the telescope has shown us a vast variety of others, whose forms are, likewise, so very capricious and irregular, that when we look at them, we feel the conviction that we are looking at something incomplete, unfinished—that these nebulæ are in a stage of progress, and that they are not explicable as the finished product of any known law. If my idea is correct, —and, certainly, so far as I have exposed it there is nothing in favor of it except a probability—we shall find, by an examination of our own Stellar Heavens, proof on every side and in every appreciable form, that their characteristic is action and not repose. That portion of the subject which conducted to the most satisfactory results, was lead in by an ingenious Englishman named Mitchell, during the last century, while making observations on the group of the Pleiades. On taking a survey of the heavens, his attention was much attracted by this peculiar cluster, and after bestowing upon it a most searching examination, he said, "it is impossible that this group of so many stars, occupying so small a space, can be accidental. It must indicate system." He even went so far as to throw out what, at that time, was a most bold conjecture, viz: that these orbs would manifest their connection in a systematic manner by developing internal motion. Unfortunately, however, in his time astronomical instruments had not been brought to such a state of perfection as would enable this conjecture to be verified. His ideas did not lead to any definite result, nor could they, as science then existed. But they were subsequently revived with great energy by Herschel, under auspices much more favorable. Herschel, however, did not know that Mitchell had preceded him in this department. His attention was directed to certain peculiar bodies found in the heavens, which we now call double stars, and which, to the naked eye, appear just like single stars. But when the telescopic power is applied to them, they are found to be two stars placed so near together that the naked eye cannot appreciate the interval between them. Previous to Herschel's time it was known that these stars existed in the heavens, but they had never been subjected to an examination sufficiently accurate to enable Astronomers to determine their constitution and the laws which guide their motions. It was not supposed that they were so near each other as they have since been ascertained to be. I will illustrate this point in the following manner: Suppose I look at these two lights from such a direction that they shall be in nearly the same line of vision. If I did not know that this large space existed between them, I would suppose, from their appearance, that they lay in the same immediate neighborhood. Here you will observe was the difficulty attending the solution previous to Herschel's time, of the problem of the double stars. But he discovered that they were in immediate proximity, and not apparent merely, as had formerly been supposed.

Herschel was attracted to this peculiar class of bodies, with reference to the problem called the *problem of the parallax*, and his telescope soon enabled him to discover that there were many more such stars than could be explained on the old hypothesis.

I think the audience will be enabled readily to apprehend the solution of this problem by Herschel, with the aid of the diagram.—Suppose our Sun to be located here in the center, the first circle to inclose stars of the first magnitude, and the second circle to inclose stars of the second magnitude. It will be seen that it may be calculated upon the hypothesis that the stars are distributed in a random or average manner through the heavens, how many of such mere optical combinations might be formed within those spheres; and Herschel discovered that the number actually existing so immensely exceeded the number which thus might be produced that a new explanation was necessary, and, in short, that the bodies must be physically and not merely optically or apparently connected. Like Mitchell, too, he ventured on the prediction that the reality of this system would be found manifested by the fact of the bodies rolling around their common center of gravity in mighty orbits: and fortunately the verification was in this case not only possible but near. The examination and

determination of the periods and motions of the double stars have constituted one of the most brilliant and fertile departments of Astronomy from Herschel's time until now. This was a phenomenon new in science, two grand primary orbs being found in special union and moving through great courses.

The periods of these double stars exhibit the greatest variety. Some are very long, while others are comparatively short. In some the revolution takes place in fourteen years. The period of one in the constellation of the Crown is forty-three years. Castor, in the constellation of the Twins, has a period of 215 years, while others extend through seven or eight hundred years. We have not been able to follow these latter through more than a small portion of their orbits; but, a small portion of an orbit being ascertained, Geometry enables us to complete the entire orbit, and by its aid we have been enabled to determine the periods of these singular bodies.

I am very anxious that the audience should realize the nature of these phenomena. They do not at all resemble the motions of our planets round their centre, the Sun. There are, in fact, two orbs or Suns of the first magnitude revolving round each other, each of which may be accompanied by a *cortége* of planets as imposing as those attached to our Sun. Neither the previous reasoning nor the observation which followed it was confined to mere Binery groups. The illustrious discoverer went far beyond these and traced the same characteristic among much more complex systems. We are now aware of numbers of triple stars which appear single to the naked eye, of others that are quadruple, and of some yet higher combinations.—The moment Herschel found that some of these bodies were triple, and discovered still farther combinations, of four Stars, he was under no difficulty whatsoever with reference to the inference he should draw from these discoveries.—He said these groups certainly are physically connected and will be found to revolve round their great centre in correct courses. The motions and periods of some of these have also been ascertained. Sometimes we find the three Stars moving around a common centre ; at other times two of the Stars are found moving round the third as their centre. You must recollect that these are combinations of Suns not one of which is inferior to our own great luminary.

Beside these, we have other combinations of four stars. There is a very beautiful one of this kind in the Constellation of the Lyre. When we look at a bright star in that constellation, it has a very peculiar aspect. It is not so round and distinct as stars usually are. On applying the telescope we immediately find the cause of this strange appearance: It turns out to be not one star, but four stars bound together, whose movements are very extraordinary. We find that each two stars constitute a double star—a system of themselves—and then the two systems revolve around a common center.—How complex and extraordinary indeed must be the mechanism that sustains a System like this.—We have boasted of our mathematics, of their accuracy, of their vast and varied powers, but when we reflect that it taxes them to the utmost to follow the comparatively simple movements that take place within our own Solar System, how useless to attempt to apply them to unwind the mechanism of Systems like these, every one of which is probably surrounded by its own System of Planets!—(Great applause.) I should mention, with respect to this fourfold System in the Constellation of the Lyre, that the periods occupied by one of these Systems cannot be less than a thousand years, and the other is about twice that, and the period before the whole System returns to its original state is not less than a million of years. But that period is small indeed, compared with some that I shall bring under your notice.

The grand fact then is established beyond a doubt, that in so far as we find minor groups within our galaxy, we discern mechanism and change, and we may venture to apply the same conjecture to still greater masses, but before entering upon that grander subject, there are a few points to which I would invite your attention. One grand fact that has been elicited by our observations upon these double stars is, that the law sustaining these wonderful mechanisms is the same that sustains our own system—the law of gravitation discovered by Newton. Those far-off suns are moving around in their mighty orbits in obedience to that simple law which causes the apple to fall to the ground, they wheel around their common centers of gravity in precisely the same curves in which our planets move.

There is a curious physical fact also connected with these double stars. Generally speaking, we find that the two stars exhibit different colors. We find them exhibiting the colors of the two extremes of the spectrum commonly called the complementary colors.

The audience must be aware that the ray of white light which we receive from the Sun is composed of a number of different colors, which are blended together in his beam. In the case of these double stars. however, we find one shining with a red light, while the other has exclusively a blue light. How extraordinary the condition of planets, if there be such attached to these variegated Suns, now basking under the blended light of both which would constitute a white light, at other times, having only a red sun above the horizon, and at others being illuminated by the blue one. If one considers how much of the characters of the living families on the earth is dependent on the action of the Sun, it will be difficult to conceive the endless varieties which must prevail among bodies subjected to so singular influences

Returning, however, to the principal subject, we find it to be the character of the minor groups within our galaxy to exhibit a systematic independence of their constituents and a consequent mechanism and motions. And now raising our thoughts somewhat higher, looking over the whole Stellar Universe, what are those mighty firmanents, those gorgeous systems lying apart in Space except special groups in regard of the great all. Is it not likely, then, that what we have learned of the minor forms may also characterize the larger ones? That just as the four-fold group in Lyra or as proudly in the Pleiads, even the multitudes of spherical clusters or those mere irregular ones are also united into separate schemes internally consistent by their own self contained activities. The question is far too wide to admit of a decisive answer. but something of a confirmation may yet be obtained from what is elsewhere going on around us. If the law of the minor groups can be extended to those mightier collocations we ought evidently to find activity prevailing also among the single suns, and as of those our own orb is what we know best, this will probably be easiest established by observing whether our sun is fixed in one portion of space or is passing onward through some great course.

The question that arises then is this: Is our Sun in motion? Is our old idea that the whole planetary system is simply lying apart in one nook of space, correct ; or, on the contrary, is our sun passing with his whole attendance of planets through some

mighty career in the heavens? This latter idea has been long entertained. It was however to the illustrious Herschel—to whom I have had occasion so often to refer—that we owe the confirmation of this great truth. His idea was this, and you will see at once that his mode of lighting upon the great fact was remarkably simple: He said, "If our Sun is in motion, how shall we ascertain the fact? We can not ascertain it by the motion of the Sun himself, because we, partaking of his motion, would not have it in our power to ascertain that motion inasmuch as we are going on in the same path. The only mode by which it could be deduced was this: If the sun were moving through the heavens, the stars around him would seem to be altering their position." Suppose for instance, to illustrate Herschel's idea, that there is a cluster of trees before me and another cluster behind me. Now if I were to move from one toward the other, the cluster which I approach would seem to be opening up, while the cluster from which I was departing would seem to be undergoing the opposite change—closing in. Now, Herschel, upon comparing the positions of the stars with their positions as laid down in the old catalogues, discovered that just exactly such changes were going on among them. In the direction of the constellation Hercules the stars appeared to be opening out, while the stars in the opposite part of the heavens seemed to be getting closer to each other. Now, said he, "Is not this all I could expect to see if the Sun was actually moving through the heavens?" Accordingly he was daring enough to infer that this was the case and he said our great Sun is moving on with all his satelites toward the constellation Hercules. Again he said, "If it be true that the Sun is sweeping through space, then it will be found that the stars in all parts of the heavens are changing; not merely those in the region toward which the Sun is moving and from which he is departing, but sideways over all the heavens will distinct changes among the stars be apparent." To illustrate again. Suppose for instance that I was moving through this room. All the objects in it, on either side of me, would appear to be moving backward. So has it been found to be with regard to the whole mass of the stars. They all present the phenomena as if they were being passed by the Sun. Since Herschel's time these motions have been scanned with the utmost precision, and his conjecture has been most thoroughly confirmed. There cannot, then, be a doubt that our great Sun, carrying all his planets with him, is sweeping in a mighty cycle through the skies. (Applause.)

These general considerations, however, have reference only to the general direction and motion of the Sun, which is probably enough for the purpose I had immediately in view; but curiosity will demand if we know aught of his velocity or the nature of his course? Until comparatively recently it was considered impossible even for Astronomical instruments, powerful as they were, to solve the great problem of the Sideriel parallax—to measure quantities so small as to determine the distances of the Fixed Stars from us. This, however, has been at last accomplished with regard to the star 61 Cygni. The actual distance of this star has been ascertained. It is 670,000 times farther removed from us than the Sun, and our distance from the Sun is, speaking in round numbers, one hundred millions of miles (100,000,000). This distance is so great that light, which moves at the rate of two hundred thousand miles (200,000) per second, would take ten years to travel from that remote orb to the Earth.

Now this star 61 Cygni has a very remarkable proper motion, moving through a very considerable space in the heavens every year. Now, since we know the actual distance of this star from us, and the quantity it is moving through the sky every year, we can convert that motion into miles and can thus ascertain how many miles it moves in a year. Now the question is, to what is this motion due, to the motion of the star or the motion of the Sun? Note the problem. The star is seeming to move every year through the sky, and now what causes this apparent motion? We find the star is moving exactly in the direction it would appear to move if *its* motion were owing to the motion of the *Sun*. We are inclined, therefore, to infer that the motion does not belong to the star, but to the Sun, and on this hypothesis we can compute the Sun's rate of motion, which is six times greater than that of the Earth in its motion round the Sun. If this, then, is at all characteristic of the amount of activity pervading the whole of our Stellar Universe, although the skies will remain fixed so long as the human race will endure, this motion will be sufficient, within the endless cycles of time, completely to change the aspect of our heavens. One can go forward, in imagination, to the time when the Constellations that now shine so brightly o'er us shall be rolled away to some remote confine of space, and their places be occupied by other suns as bright and beautiful as they.

If we are going toward this star 61 Cygni at the rate of four hundred thousand (400,000) miles per hour, we will reach the extremity of our Stellar Cluster in about two hundred millions of years! (200,000,000.) These periods may seem incomprehensible. They indeed seem vast compared with human annals, but they are brief when laid beside the annals of our Globe. If Geology is not the sheerest fable—if we are not to return to the old conceptions, that the rocks with their entombed creatures have been laid down there purposely as the most mocking of enigmas—enigmas that seem to have meaning and yet have none—then during the vastest of the periods of which we have been speaking, our chief existing mountains were in being, rearing their peaks toward different constellations and surviving in their littleness and fragility even these immense transitions. Extend now what seems true of the Sun to his other associated orbs and where is the repose—where the stability of our Heavens! Because those very stars which shine on us, also shone over the Chaldeans; we spoke of their changeless rest, of their arrangements as being eternal. Alas! no, neither Space nor Time are theaters of repose, and even our most stable existences are the seats and subjects of activities and ever revolving change, whose ultimate object is known to God alone.

It seems, then, ladies and gentlemen, as far as we can judge from the aspects of the bodies around us, that we may consider our great cluster as being in ceaseless activity; and that, therefore, those other clusters whose character I intend to bring before you, are subject to something of the same destiny. If this is the case, how little wonderful is it that their shapes seem so capricious. There is nothing relative to them that is entitled to the name of stability, and we can view them only as exhibiting to us the phases of the successive steps of an immense progression. The kind of knowledge that we can alone have with respect to them, even should they be watched during the entire existence of the human race, is something like what we would learn concerning the terrestrial arrangement around us, if our knowledge were gained from a single glance of the eye, which was then shut again forever. [Applause.] No more, probably, than so passing a glance will man ever attain concerning the destiny of these nebulæ.

I shall venture no farther amid these immensi-

ties. I shall not mock your imaginations by proposing to conduct them to still higher regions, away from the contemplation of the separate clusters up to the Universe as in aggregate, in which each stupendous group is only an individual. I shall not speak of these as related even like the single stars or of the awful motions and careers which must spring out of such relationship; but retiring at once from grandeurs it is not yet given to the human eye to contemplate, and from hights too dizzy for the firmest reason, let me conclude with one remark on a question that profoundly interests us all. Looking at these mighty motions occupying the infinitudes of space and apparently carrying on the great Universe through a course of majestic and ever varying developments, one cannot resist the inquiry, what are the forces that shape and sustain them? I do not mean the mere technical definition of these forces, but what is their relation to the Divine Mind? What true notion indeed have we of force in itself? When we speak of the power or force of gravitation, for instance, what is it that we really mean? Has the word a distinct idea attached to it, or do we merely deceive and confuse ourselves by a phrase.—We use the word power to express something that upholds an order, but on a close analysis of the material Universe we do not find aught existing there beyond simple sequence. Events follow each other in a regular order, and beyond this the Universe itself informs us of nothing. We cannot, however, get rid of the feeling that this order must be supported by something corresponding to an action of power or force, and therefore we feel impelled to inquire still more closely, whence we obtain our idea of power? Now it appears that this conception is obtained wholly from our experience of our mental actions. It is in fact synonymous with our conception of a free spiritual act, and therefore it seems necessary in order that the Universe be comprehensible that we recognize Deity not merely as the Creator but as the ever-present Preserver, Sustainer and efficient Cause of all phenomena.

This then, awful though it is, is the true, ultimate, scientific idea of the Divine Omnipresence. Law is not even the Almighty's minister; the order of the material world however close and firm is not merely the Almighty's ordinance. The forces if so we name them, which express that order are not powers which he has evoked from the silences, and to whose guardianship he has entrusted all things that so he himself might repose. No! above, below and around them is God, there his universal presence speaking to finite creations through finite forms a language which only the living heart can understand. In the rain and sunshine, in the soft zephyr, in the cloud, the torrent and the thunder, in the bursting blossoms and the fading branch, in the revolving season. and the rolling star there is the Infinite Essence and the mystic development of his Will. [Great and continued applause.]

LECTURE III.

The Solar System....Its Plan and Mechanism....Laws governing Motion....Gravitation....Centrifugal and Centripetal forces....Copernicus....Newton....Galileo....Kepler....Euler, Clairaut and D Alembert....Les Bernouillis .....Maclourin....Lagrange and Laplace....Adams and Leverrier....Discovery of Uranus.....Its strange movements....Discovery of the Planet NEPTUNE....Sublime position of Leverrier before the Royal Academy of Paris....Concluding remarks.

Prof. NICHOL remarked, previous to commencing his lecture, that he had, after mature consideration, concluded that it would be advisable to divide the lecture announced for the evening into two lectures, as it would be impossible for him to do the subjects which he wished to present to the audience anything like justice in one lecture. After the applause with which this announcement was received had subsided the eloquent Professor spoke as follows:

LADIES AND GENTLEMEN: I proceed to expose, as arising out of the mechanism of our Planetary System, through effect of Man's profound and triumphal exploration of its secrets, a discovery than which the entire annals of Physical Science probably present none more brilliant or apparently strange—to endeavor to remove the difficulties and doubtfulness with which that remarkable achievement has seemed to some to be surrounded—and, if I can, to clear away all obscurities connected with its history.

I feel persuaded that it were needless, even at the outset, to dwell with any special attention on the outline or general constitution of our Planetary Scheme, for they have for the most part passed, as the ages have coursed along, among the details of common knowledge; but since the entire discoveries, whose steps we shall seek to follow, is but a deduction from that constitution, I do trust I will be pardoned if, even here, I seek for the sake of future distinctness to exhibit to you as succinctly as possible the most important of the elementary facts relating to our System to which we shall require frequently to appeal.

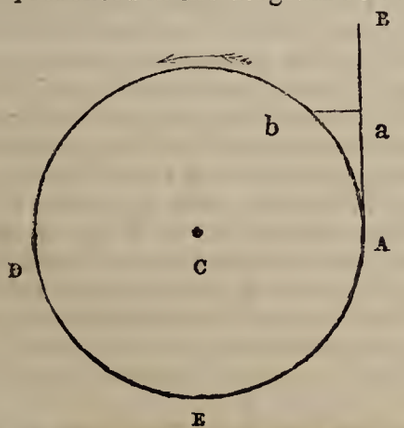
I need not more than refer to the Planetary System, which, as we first descry it, is alike simple and majestic. Resting in one portion of Space, from which his lustre is diffused through the profundities which environ him, is the Sun—our magnificent Luminary, ranking in glory and corresponding in destiny with the myriads of the fixed stars.—Around this orb, which illumines, cherishes and upholds them, those smaller worlds—of which our Earth is one—roll, with admirable and unwavering regularity, at divers distances and in stated periods. Nearest of all, as shown in the diagram,

is placed the planet Mercury; next in remoteness we descry the brilliant Venus; then our Earth with its Moon; then Mars; then that complex group of small planets, [Asteroides,] remarkable through their extreme diminutiveness, and also because the orbits in which they move so nearly approach each other, that one mean distance might almost be taken as indicating the position of them all; behind these lies Jupiter, with his satellites—the noblest and most beautiful among the secondary constituents of our System; then Saturn, with his Moons and remarkable Ring; and finally, the planet Uranus, which, until the advent of these latter revelations, we deemed to be at the outer limit of Planetary existence—the remotest of the regular globes attendant on our Sun.

This plan, so simple in itself, was not easily discovered by mankind, and was not arrived at till after long years of perplexity and toil. The discovery of it gave immortality to the name of COPERNICUS. This discovery, grand and sublime though it was, did not satisfy the ever active human mind. The question speedily became, not merely in what order are these various orbs located, and in what manner do they move?—but, Can that mechanism as a whole, be reconciled with any known mechanical principles—are these arrangements of the Heavens indicative of the presence of Laws whose efficacy we discern among the changes more immediately around us? It was the answer to this question that bestowed immortality upon the great Englishman, SIR ISAAC NEWTON. Prior to his time—

chiefly, in fact, by the sagacity of GALILEO and JOHN KEPLER—one grand principle, characteristic of the habitudes of all bodies in motion, had been satisfactorily evolved and apprehended. It was this: *Every body, on receiving an impulse or other disposition to move, will move onward in a straight line, in the direction of the impelling force, provided it continue undisturbed by any other force.*

Now, on a first glance at the system of the planetary motions, it is manifest, that these orbs do not move in straight lines, but in *continuous curves;* and therefore that their existing condition cannot be explained, by the mere supposition of their having been once set in motion by a special impulse or force: nay, it follows immediately, that, to this primal moving power, the action of some other disturbing force must be added, so that the phenomena be explained: and a little deeper consideration will show, that this second force cannot be one that has merely acted at a cerain epoch and then ceased; but that, on the contrary, its energy is unceasing or *continuous.*—Let us reflect for a moment on the condition of a body moving in a *circle,* as represented in the diagram below.



It may easily be made plain that the body A, revolving through the circle A, D, E, around C, cannot be conceived, at any point of its course, to move, merely in obedience to impulses previously given it, and free from other restraint. When at A, for instance—whatever these former impulses—its tendency, were it free, would be to dart along the line A B, exactly like a stone released from a sling; so that its natural course would be A *a,* instead of the circular one A *b;* and we cannot imagine it pursuing freely the latter path, unless some other power act on it *continually*—drawing it from the right line toward which it inclines, downward at every moment, in the direction *a b.* There is thus needed a steady and unintermitting *deflecting* power—capable of bending straight lines like A B, into such curves as constitute the orbits of the Planets—to render in anywise intelligible the order of our Solar System: and our great countryman at once discerned that, the inquiry into the nature of this second and necessary Force constitutes the fundamental problem of Astronomy.—The leading characteristics of the second Power did not long escape the persistent sagacity of NEWTON. He discerned, almost on his earliest glance, that it must be a power directed toward the center of the Sun: so that the condition of each Planet seemed to be this: It is sustained in its actual course, by the conflict and equilibrium of two forces—one, the result of the first impulse, or cause of its motion, which would induce it to fly off into space; and another, a restraining power in uninterrupted action, which *of itself* would cause the body to pass toward the center of the Sun. Animated by this center-seeking tendency on the one hand, and the *centrifugal,* or center-flying tendency on the other, the planet Jupiter, for instance, rolls his unceasing round in a path subject to no accident, and, in as far as this goes, incapable of change: and as it is the same central authority, merely changing in strength, along with the distance of the body from the Sun—which affects all the orbs of our System—from Mercury ever hid within the solar rays, to the remote and inhospitable Uranus; its mechanism appears as simple as its plan—the result of only two of those primary ordinances, that guide the phenomena of Motion. Many profound inquiries—deeper indeed than Man has the power to resolve—are inevitably suggested by the scheme whose simplicity has thus burst on us. What, for instance, is this *power* which binds all these orbs to the Sun's center? ATTRACTION, GRAVITATION—these are the names we have bestowed upon it: but what mean they? what the idea we are entitled to attach to them? Our positive knowledge, indeed, goes no farther than this—that the *order* of the planetary motions can be expressed by a certain Law; that the places each orb occupies successively, in the course of its revolution, admit of being so joined together; or denoted in their totality, by the central influence we have assumed. Is Gravitation, then, only a name for this succession? Or rather, is it not the apparition of some primal Force or Power, which by the order it bestows on material events—manifests its character and influence? *This,* at least, we know—far as our ken at present extends, whether we follow those singular and majestic activities among the double, triple, and quadruple stars; or adventure still farther, even among those awful adyta where the mightier groups of the Stellar Universe take on their forms and significance—the influence of this august Law ever meets our gaze, preserving through all that exists, its matchless order, and in silence elaborating those more perfect developments, which will occupy the Durations to come. (Applause.)

I mentioned in my last Lecture, that we find this Law acting in the most remote systems exactly as it acts in our own. Yes! this subtle Law diffuses itself throughout all Space, and curbs with its irresistible might the wayward tendency of the most majestic and far-off orb. (Applause.)

The account of the mechanism of our System, which I have just presented, is very far from being the correct or completed one. We shall find it necessary, indeed, for the sake of distinctness, or at least highly advantageous, to begin our investigation by realizing even this imperfect view; but it conveys little conception of the actual structure of a Scheme, which is as complex as that representation was simple; and which, so far from presenting the orbit of any planet as the balance of only *two* tendencies, derives it from the equilibrium of sympathies alike multiplied and changeable—sympathies, uniting by some invisible bond not the planets with the Sun merely, but every atom of matter within our System with every other; and diffusing throughout its entire domains a unity so perfect and comprehensive, that it most resembles the wondrous vitality of some organized and sensitive framework. The principle of that unity is as follows: The Attraction or Gravitation which, by drawing the planets toward the Sun, restrains them within a definite curvilineal orbit, is not, as we have just supposed, confined to the Sun, or exemplified by his action, alone. Speaking of it in the usual, and, I believe, also in the most correct manner, *it is an energy or force exemplified by every particle of matter.* So universal is this energy, and so unlimited its sphere, that even this mote that I hold in my hand sends forth an effective notice of its being, to the remotest orb among the profound recesses of space; nay, alter its relative position by a quantity however small, and your act is felt throughout the unfathomed Universe! The amount

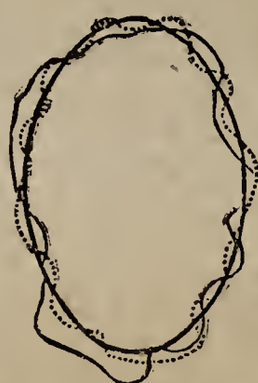
of influence it exerts, it is true, is slight, unmeasurable, infinitessimal; but nevertheless an influence it does exert on the remotest Orb that wings its mystic flight through Space. Before the vision of a harmony so unbroken, of a mechanism so vast, so complex, and yet so perfect, the thoughtful mind cannot avoid being penetrated with awe! Yes! this Fabric is indeed the offspring of Omniscience, and under the care of a government which protects alike the majestic and the feeble—within whose august, whose perfect harmonies, the fragile lily issues from its stem, robed as the most beauteous queen, and the feathered songster pours forth those bursts of melody which are heard even amid the solemn music of the stars. (Great applause.)

There are two special points in the Solar System, as we must now view it, to which I would here solicit particular attention.

The simplicity of the conditions under which each planet performs its motions has now vanished utterly away. Not only is it attracted by the Sun; but—since Gravitation is universal—by every other orb having part among its arrangements. Refer once more to the Diagram of the Planetary System, and observe the case—say of the planet Jupiter. That orb indeed still obeys the influences I formerly adverted to, viz: his own tendency to fly off into space, and that counteracting tendency in virtue of which he would, if unchecked, move toward the center of the Sun: but beside, he is pulled by all the other Planets, in most various directions; and not only with various, but ever-varying forces, inasmuch as each is dragging him toward itself with an energy depending on its size and distance; and that distance is—through those motions which are the life of the system—always changing. It is true indeed, and will be readily manifest, that of all these powers whose office it is to give the planet a curvilineal instead of its natural rectilineal path, the energy of the Sun is by far the most important; for, as I have said, one element in the efficacy of the power exercised by any body over another, is the *magnitude* of the deflecting body: and the Sun immensely transcends the aggregate of all the Planets, which indeed are rather his subordinate attendants. The Sun's action, then, *still determines in the main* the path of Jupiter and these other orbs; and the action of the neighboring planets only *disturbs* this path, or impresses on it certain changeable irregularities. For instance, if the Sun alone had acted, Jupiter would revolve around the central luminary in a perfectly true, or accurate geometrical curve, viz. the Ellipse: and that Ellipse may still, as below, be deemed the *normal* or *mean* path of that Planet—his real one vibrating around it, as in the fanciful curve in the same diagram—a curve which is not reproduced year after year, but which will pass through as many variations as the course of ages can witness, in the relative positions of the constituents of our multiplex scheme. To determine that normal ellipse in the case of any Planet, might have been no arduous task; but how different with these deviations from it—these ever-shifting *perturbations!* The fidelity with which he can trace and estimate directions and quantities so mutable and evanescent, is the highest attainment of the Astronomer; an object indeed most worthy of those toils that have occupied him since the lifetime of NEWTON. Many a midnight has been consumed in the arduous pursuit: and success in the most difficult portions of the enterprise, has conferred on several names a distinction that will never die.—

Before me in greatest brilliance arises that illustrious triumvirate—EULER, CLAIRAUT, D'ALEMBERT; on one side of them the great family of the BERNOUILLIS: on the other, our own MACLAURIN; and in later times those two chiefs, seated on twin summits—LAGRANGE and LAPLACE; from whom, again, the mantle has descended and fallen on men most worthy to wear it—a company goodly in number and ardent with hope; among whom, however, the eye easily discerns—as ever conspicuous—those illustrious fellow-victors in the race, ADAMS and LEVERRIER. (Applause.)

The modification of chief moment, however, which this completed idea of Gravitation impresses on our conception of the Solar System, is this; No part of it can be regarded as *separate* or independent,—each orb being *united* by ties which cannot be severed, *with all the others*, in regard of the chief features of its being. So long as we regard the Sun as the sole seat of this attractive energy, any Planet might be removed from the system without other consequence than the disappearance of a Star from our skies:—annihilate Jupiter, for instance, and all others would, in that case, roll onward precisely as before, in courses perfectly determinate and geometrically regular. But if the merest pebble on a beach cannot be removed, without remote stars discerning its change of position, how entirely impossible this unobserved annihilation of Jupiter! Nay, so far from any planet being independent, or, as I should rather say, severed from relations with the great Universe (for such, in the present case, is the meaning of *independence.)*—if we restrict our thoughts to its motions or orbit, and to its absolute magnitude, that Planet may be said to be *determined by, or to be the result of, the concurrence of the habitudes of all the others.* In the case of Jupiter, for instance, suppose him concealed from my sense of vision, by being bereft of his power to reflect the radiance of the Sun;—so long, nevertheless, as he rolls in that orbit, his presence must be revealed to intellectual vision, by his influence on the motions of the orbs within his reach: yea, the irregular and then unaccounted-for motions of Saturn, would point toward the reality of that Planet; and could we aright interpret them, they would unfold alike the magnitude of the force that has caused them—or, what is the same thing, the mass or weight of Jupiter—and also the variability or changeableness of that force, which, being interpreted, signifies the orbit and motions of Jupiter—even as *unerringly and unceasingly as the movements of the mysterious needle tell of the direction and intensity of the Influence toward which it turns.* Let the regular line represented in the diagram below, for instance, be Saturn's orbit, in so far as that is due to the Sun, and the unbroken irregular line, his real orbit. Now, if



the dotted line indicates the orbit that Saturn ought to assume in consequence of the action of all known planets except Jupiter; then the discrepancy between these last two, viz: the irregular unbroken and dotted lines; would point to *the foreign influence;* and nothing save the requisite skill could be wanting to enable us to reach, through these unexplained deviations, the reality and definite habitudes of Jupiter. *Definite,* I say, for in consequence of our thorough knowledge, not only of the reality of Gravitation, but of the precise mode of its dependence on the magnitude and distance of the bodies exercising its power—there is now no

room within the range of such an inquiry, for *chance*, or toleration for *vagueness:* to reach the fixed and definite conclusion in regard of any point to which inquiry is directed, needs *skill alone*—This hypothesis of a successful search for an opaque and invisible Jupiter, is not, however, merely an illustrative one; it is, on the contrary, the equivalent of many investigations, that are far from strange in Astronomy. For instance, we read in works on that science—often indeed to the marvel of those who know not our technical proceedings—of the WEIGHTS of the several Planets; which are spoken of with as little hesitation as if they had been weighed in our terrestial balances. Now, these are deduced in this wise: A planet being disturbed by its neighbors, its movements are watched and scrutinized, while the deflecting bodies occupy with respect to it *all variety of positions.* The effect due to each, is thus esparated from the total effect; and from the amount of its influence, the mass or weight of each planet is inferred: nay, speaking more generally, this process of determining important physical attributes of these orbs, by inference from their attractive influences, has constituted the principal branch of physical Astronomy from NEWTON'S time until our own. Shall I dwell, in illustration, on the lights thus obtained regarding the *shape* of our own Earth? That body, like all globes in rotation, is a spheroid flattened at the poles, or bulging out—as if into an attached *ring*—at the equator. The determination of the precise shape of the Earth, being of consummate consequence to geographical science, several of the greatest of our European States have instituted vast triangulations—some of them in remote regions—that, by the sure methods of the Surveyor, this character of our globe might be defined. Results of high accuracy have undoubtedly been reached by such labors; but with all their importance, they are not superior to intelligence, which on the same subject has reached us from the *Moon.* The motions of that orb are not what they would be, had the Earth been *a perfect sphere.* Certain deviations are caused by the influence of our equatorial protuberance: and these deviations—measured by our modern instruments whose precision approaches to the marvellous—enables us, by inverse reasoning, to determine, with undoubted exactness, how far the Earth deviates from a regular globe. It is certainly unnecessary to accumulate illustrations of a point concerning which the whole modern history of Astronomy is most rich and emphatic: let me conclude, therefore, with an allusion to that recent grand generalization of the deeply-lamented BESSEL, which has unfolded the probability of opaque orbs large as these spangling suns, revolving with a Sirius or a Procyon, around some common center; thus appalling our imagination, already bewildered amid the excess of visible glories, by the unexpected and overwhelming idea, that the objects which light reveals, may, after all, constitute but one class, or one special though splendid scheme, amid this profusion of created magnificence! (Great applause.)

The method of this discovery of BESSEL'S—one of the most remarkable of modern times—and the reasoning on which it reposes, are too remarkable to be permitted to escape with a transient notice. Every star in the Heavens, it is known, has an apparent proper motion;—sometimes that motion being altogether *apparent,* and in other cases *real.* While studying, with his usual care and sagacity, the changes of place exhibited through a long series of years, by SIRIUS and PROCYON, Bessel saw that they evinced a real proper motion, of a very singular description. In both cases the Star OSCILLATES—that is, it moves backward and forward like a pendulum. Like NEWTON of old, BESSEL marked this as an *unnatural* motion—one opposed to every known principle in mechanics. His first inference, then, was, that the oscillating motion is, in reality, a motion in a *circle,* or other curvilinear path, turned nearly *edgeways* toward us, and therefore taking on the appearance of an *oscillation.* But the investigation could not stop here. If the path is curvilinear,—that must be owing to a *continuous deflecting force,* as NEWTON held in regard of the Planets: and since no Body is visible around which either Sirius or Procyon can be supposed to revolve: the conclusion is, that the seat of this great attractive influence is *opaque*—concealed forever from the sense of vision. The inference is so logical that we may not repudiate it: Surely, however, it is most wonderful—bringing the strange intelligence, that those brilliant orbs are, after all, but one class or species, amid the luxuriance of Creation! (Applause.)

Thus, then, Ladies and Gentlemen, have I concluded my exposition of the plan, mechanism and governing laws of our great Planetary System preliminary to the unfolding of the process by which a mighty world was evoked from the boundless confines of space. It has occupied longer than I anticipated; but, if I have been apprehended, what follows will be easily understood.

The researches of Physical Astronomy, conducted with regard to the problems I have attempted to describe, were rapidly perfecting our knowledge of the Planetary System, when, in the year 1781, the illustrious Herschel altered our conceptions of its extent, by the accidental discovery, of the orb that for some time bore his name, but which is now universally recognized, by the more congruous appellation of Uranus. I say accidental for it was by mere chance that Uranus was discovered. Herschel with his immense telescope had been examining the Heavens for many nights, when to his great surprise he beheld one evening an orb having a disc. Now our fixed Stars have no discs, that is they have no surface that is measurable. They are so remote that when viewed through the most powerful telescopes they present nothing but a mere lucid point. So Herschel at once determined that this orb could not be a fixed Star. He noted its place in the Heavens, and on the next favorable night he observed it again, when lo! it had moved from its former position. He then concluded it was a Comet, and his first papers in relation to it were called "Papers on the discovery of a new Comet." But upon bestowing upon the mysterious stranger a more searching examination he soon discerned that it was not a Comet, but a Planet! farther away than Saturn, revolving round our Sun and belonging to our System. Now perhaps it will at once occur to you, why had not the existence of a Planet beyond the orbit of Saturn been suspected before this accidental discovery of Herschel? If all I have been saying about Jupiter be correct, why did not Astronomers ascertain that there were motions in Saturn and Jupiter that could not be accounted for except by the fact that there must have been a Planet beyond Saturn? If our acquaintance with the various motions of Jupiter and Saturn—the two Planets chiefly within reach of the influence of Uranus—had been as perfect as it is now, the existence of this superior orb would certainly have been suspected prior to its discovery by observation, or had Uranus remained undiscovered to this day, its existence would most certainly be inferred from the motions of the other Planets and it would be soon hunted up. But 1781 was a long time ago in the Science of Astronomy. Art had not then enriched us with those splendid instruments, which in modern times are recording quantities all but evanes-

cent; and the discovery, therefore came to the scientific world with the freshness of a surprise. The existence of those connections, however—although they had escaped our previous observation—was not in the least degree problematical; and accordingly the task of modifying our previous conceptions of the mechanism of the system, so that Uranus should enter into it as an essential element—present, not merely in its observed place, but, by its influences through the whole system—was placed before the Astronomers for solution, immediately on the discovery of the existence of that orb. Now, this problem evidently concerned—*first*, the question of the precise path of Uranus—the *real curve* it describes in its revolution around the Sun: and there are two very essential points as to this matter, requiring peculiar notice.

The problem itself is this: *From a number of observed places of Uranus, to determine its entire path.* It is not necessary to follow any planet through its *entire course*, in order that we lay down the path it regularly pursues. Observation so complete, would be needful only if we had no conception of the *kind* of path in which a planet must be moving; but, since we have a thorough knowledge of the grand LAW that regulates the movements of every orb belonging to our system, a few observations suffice, to enable us to conclude concerning any orb's *entire* habitudes. This should not appear strange or impossible. Recollect the discovery of those remains of animals, by CUVIER, who upon finding a few bones imbedded in a mound, was able to restore a part of the animal creation that had been extinct for ages. A bone or a tooth of an animal found—in your "big bone lick" is enough to enable the Naturalist to determine to what class of animals it belonged. Just so it is with the Astronomer.

Give him a fragment of a planet's orbit and from that fragment he will deduce the planet's path around the Sun. (Applause.) At the very outset, then, we assume as the groundwork of our Theory of any Planet—and of course with regard to Uranus—*the integrity of the Law of Gravitation in the regions through which that planet moves.*—The problem, on the ground of that assumption, is as follows: Reverting to the mode in which every planet must move, as formerly represented by the diagram, it will be seen that the phenomena of that motion are divisible into two parts—*first* the normal Ellipse, depending on the action of the Sun; and, *secondly*—the deviations from it, caused by the disturbing action of the Planets. The two sets of phenomena, however, although distinct, cannot be determined *apart from each other:* it being clear that until we know something of the normal ellipse, we cannot compute the deviations, as these depend on the *distance* of the Planet from *all the other bodies* affecting it: and again, so long as we do not know the amount of the disturbances, we cannot fix how much to take from or to add to, the observed place, in order to arrive at the normal or undisturbed Ellipse. The problem is therefore by no means an easy one: but when our results do not agree with prolonged observation, it is always open to us to try *the effect of an alteration of the normal Ellipse*,—an alteration, however, within limits—viz. the possibility of explaining the deviations from the curve on which we fix, by the action of known perturbing bodies. The solution, it will be seen, depends, in every view of it, *on our knowledge of the mode of the action of these disturbing bodies.* This knowledge must be clear and definite; or we can reach no solution at all. If any unknown body, for instance, acts on Uranus, then the foregoing principles could never enable us, from a few observations of its place, to determine its true path: no more than the naturalist could arrive at satisfactory results if he were to attempt to work with the tooth of one animal and the thigh bone of another while supposing them to belong to the same animal. And therefore the work of Astronomers must in every such case involve this other supposition—that *we are acquainted with all the bodies that act on the Planet.* Any solution—so far as we have yet traced its progress—thus necessarily involves three uncertainties, viz:

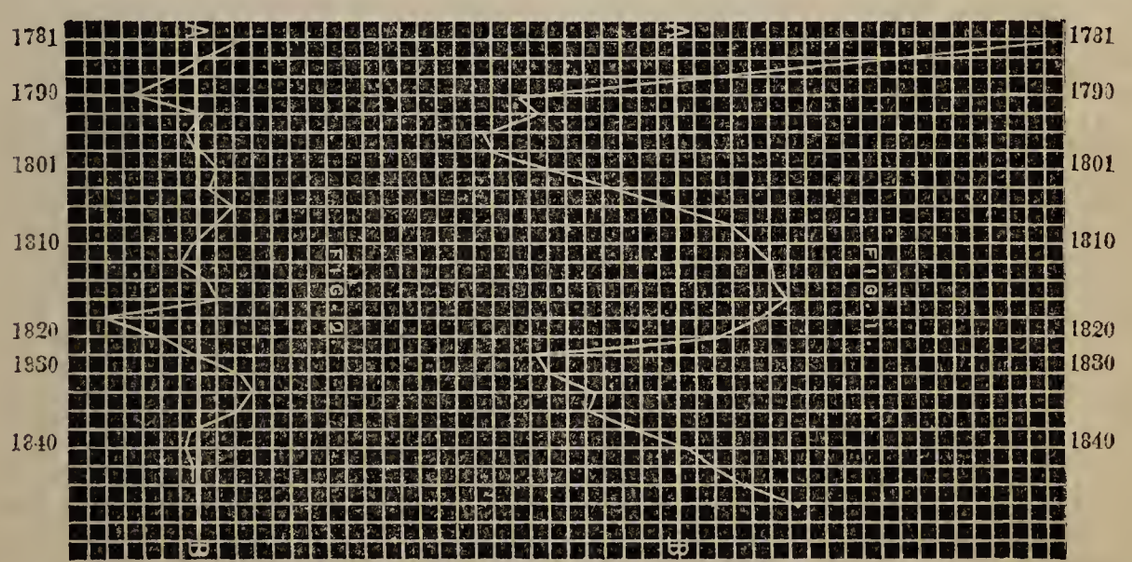
(1.) *The assumption of the unmodified action of Gravitation in regions so remote from the Sun as Uranus*

(2.) *The assumption that we have fixed on the true or normal ellipse.*

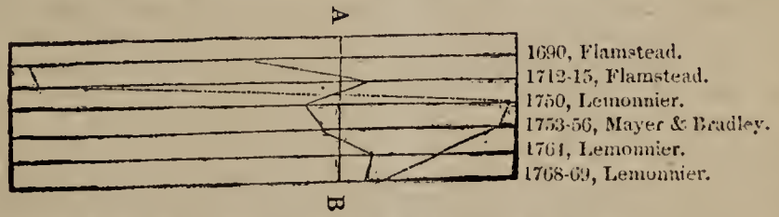
(3.) *The assumption that all the disturbing bodies are known to us.*

It cannot be difficult to apprehend that, in an inquiry like that I have described, the facility of reaching a conclusion, and the certainty of reaching the just one, must largely increase with the extent of that part of the orbit through which Uranus had actually been traced by observation; just as in the case of the Naturalist who, although he *could* arrive at correct conclusions with but a tooth to aid him, would be able to work much more speedily if at the same time he had a thigh bone of the animal as well. A very few observations, if they were accurate, and if all the disturbing influences were known, would, in event of our possessing adequate command over Theory, enable us to obtain a right knowledge of the orbit; but should any of these conditions fail, it is clear that the greater the number of the planet's observed places, the sooner would our defects be observed and remedied. Now, M. BOUVARD, who, after 1820, undertook to form tables of Uranus, or, in other words, to deduce the entire orbit of that Planet from observations made during the forty years that had elapsed since its discovery in 1781, found, on due inquiry, that it had been seen at least fifteen times previous to its discovery by Herschel, and recorded in old catalogues between 1690 and 1771 as *a fixed star*. The record of these positions did not, of course, detract in any way from the merit of Herschel's discovery; which was, not that he saw a new star, but that the star in question was a *Planet;* but it clearly very much limited the possibilities of unrecognized error in any theory of the body's motions. For instance, if in any circle, one writes down one set of dots to represent the places of the planet between 1781 and 1820, and another set to indicate those places between 1690 and 1771, it will be readily observed how little remains to be inferred, if we take both sets into account; compared with what would remain to be inferred, if only one set had been established by observation; and it was no wonder, therefore, that BOUVARD welcomed the fact that the planet had—unconsciously—been so often seen before. On the completion of his calculation, however, he met with a most extraordinary and puzzling circumstance: *The orbit he deduced was found unsatisfactory to either set of observations, and its deviation from the older ones was altogether remarkable;* in other words, he found that the very circumstance which should have enabled him to crown his effort with complete success, was that which, from some unexpected cause, rendered success impossible. So long as he took into account both sets of observations, or, what is the same thing, so long as he took all available precautions to avoid error regarding the habitudes of Uranus—the results of his inquiries seemed entirely erroneous; in other words, they gave an orbit inconsistent with the facts on which the calculations were based. It farther appeared, that if either set of observations was assumed by itself as the basis of the orbit required, a

result came out sufficiently concordant with that set, but wholly discordant with the other set; so that BOUVARD was obliged to conclude that these two classes of facts were *incompatible:* and the next point was, what could be the reason of that incompatibility? Perhaps no conclusion was so probable at the time as that to which BOUVARD, amid much misgiving, saw it expedient to come; viz. that the old observations might have been less accurate than the modern ones, through the imperfection of the old instruments; and that, therefore, they should in this inquiry be set aside. The conclusion was indeed a bold one, I had almost said *audacious:* for among the observers on whose authority these old places of Uranus reposed, we find MAYER and the industrious FLAMSTEAD, and, far above all, our incomparable BRADLEY: nor was the ingenious Frenchman blind to the difficulties encompassing the course he found himself constrained to choose. "Such," says he, "is the alternative presented by the formation of the tables of the planet Uranus, that if the ancient observations are compared with the modern ones, the first are passably represented, while the second are not so with the precision they demand; and if either set be rejected, tables are the result which satisfy the ones retained, but do not satisfy the others. It being then necessary," adds BOUVARD, "to decide between them, I have held by the modern observations, as being the most likely to be accurate, and I leave Time to come in aid of the difficulty of reconciling these older ones, and of explaining whether it is caused by the inexactness of these old observations, or depends on some foreign and yet unperceived influence to which the planet is subjected." And a very satisfactory light in regard of the difficulty was quickly afforded by "time." If BOUVARD had been right, then the movements of Uranus subsequent to 1820, would necessarily have agreed with the orbit deduced from the observations between 1781 and 1820: but, on the very contrary, *the planet has since been moving apparently without the remotest regard to that orbit, and in defiance of all known rule.* Not only, then, was it necessary to reject the old observations in order to sustain the authority of Bouvard's determination, but those more recent ones in regard of whose authenticity and scrupulous correctness, not a shadow of doubt could be intimated, had also to be summarily thrown aside. As with KEPLER, in his pursuit of the true orbit of MARS, no sooner was the Planet, in one part of its course, brought under control and properly enchained, than, lo! at another part he broke from all bondage, and rushed wither he would! The actual state of this very puzzling case is represented in the following diagrams:



If the line A B, in fig. 1, represent the observed orbit of Uranus, the broken line will exhibit the theoretical orbit,—that calculated from the epoch 1781 to 1840 being traced by the irregular line. Now, the deviation of the two lines—one-tenth of an inch corresponding to one second of space—is the measure of this discrepancy between *Theory* and *Fact;* a discrepancy which in *degree* had no parallel elsewhere in Astronomy. Turn, however, to the diagram below, where the line A B again re-



presents the observed orbit as determined by those separate acts of observation between 1690 and 1771. The dotted irregular line, on a scale only one-half of the previous one (a second being represented by half a tenth of an inch,) is now the representation of the theoretical orbit of BOUVARD! No marvel, indeed, that Uranus had come to be accounted the puzzle of our science,—no wonder that so many minds were turned to this portion of the celestial mechanism, in confident expectation that the anomalies would in time be resolved, by the occurrence of some capital discovery.

How difficult it is to follow, in our inquiries, the easy rules laid down by the immortal VERULAM! Even when the temptations to go aside are slight, men will not confine themselves to the only road that can ever lead to a revelation of the secret processes of Nature: on the occurrence of any difficulty, they set a-guessing instead; not after that only legitimate fashion—the way in which Genius apprehends, combines, and follows the applicable analogies that lie around it—but literally almost at random, and with no apparent aim save the desire to avoid confessing that there exists something, of which, in the meantime, they know neither the method nor the cause. It were positively tedious,

were I to enumerate the varied fantasies brought forward, not without adequate solemnity, as probably satisfactory, regarding these remarkable discrepancies; nor shall I refer, and that very briefly, except to two. In the first place, the discrepancies were supposed to result from *accident*—not to belong to the *order* of our System, but to originate in causes of *disorder*; and, according to established custom, alike in Astronomy and Geology, the action of a Comet was invoked as the *magnus Apollo!* One of these wandering bodies, it was said, had, in the course of its devious path through our system, come into contact with Uranus—struck it, in fact; and, by introducing a new cause of motion, produced the discrepancy we discern between the course of the planet at the epoch of these oldest observations, and its subsequent movements. It is perfectly certain, indeed, that such a disturbance would have produced a great deviation, or apparent breach of continuity. The planet's path would, in that case, have consisted of parts of two different orbits, joined at the point of concussion; but even if its course prior to and after 1780 had been parts of two independent orbits, internally consistent or harmonious with known law—*which they are not*—is it not clear that another comet and another shock were requisite after 1820, to account for the second breach of continuity—that second departure of the planet from the course laid down by BOUVARD? If *one* accident might, without the support of observation of the fact, have been received as possible, the occurrence of *two* such is opposed by all the laws of probability; and the hypothesis might, accordingly, have been rejected, even without the elaborate demonstration of its inapplicability to the details of either case. Nay, this consideration goes farther, it forbids our referring—unless distinctly upheld by observation—the anomaly to any accident whatever; for it is quite inadmissable to suppose the *recurrence*, in circumstances so similar, of what in its very essence is *capricious*—an exception, by hypothesis, to all known law or order. We must dismiss, therefore, the hope of receiving a solution from *accident*.—Another assumption which received high favor, must also be mentioned here, as of the kind I term preliminary. The calculations of BOUVARD, it will be noticed, rest wholly on the supposition of the integrity of the law of Gravitation: now, may not these resulting inconsistencies *have their root in the erroneousness of this fundamental assumption?* The law of Gravity extends as far as Saturn: but, may it not have undergone modification, in those profounder remotenesses from the Sun, through which Uranus revolves in its circuit? This view seemed at one time a favorite with the illustrious BESSEL: nor has it, on the occurrence of other difficulties, been deemed illegitimate to consider it possible that Gravitation *may* alter. In truth, we have no reason to suppose this great Law, as now revealed, to be the ultimate or simplest, and therefore the universal and all-comprehensive form, of a great Ordinance. The mode in which its intensity diminishes with the element of distance, has not the aspect of an *ultimate Principle;* which always assumes the simplicity and self-evidence of those axioms that constitute the basis of Geometry: but there is a rule in philosophy, applicable to this matter, that admits of no dispute. Allowing fully that very few Laws, as discerned by Man, can be deemed essentially universal—none, it may be, except those first principles of the science of Form, by which so many of the relations of different parts of the Universe are determined;—it is yet clear that we are never entitled to challenge the universality of Laws that, within our experience, have nowhere failed—*until every other mode of overcoming the difficulty has proved of no avail.* If the law of Gravity must be challenged, then, the time for that is not at the beginning of our consideration of this difficulty; but *after* we have tried every circumstance, which—the law remaining entire—might affect the manner of its working, and so have demonstrated that what is now an apparent contradiction, may not be only one of its more recondite and least obvious results.—We must postpone, therefore, that Inquiry, although it had the merit of receiving the approbation of BESSEL.

Dismissing the idea, then, that such anomalies can arise from accident, and postponing the challenge of the Law of Gravity until every other resource has been exhausted—we find ourselves between the following alternatives: Either we are ignorant of all the conditions within which Uranus is moving,—*i. e.* we know not the whole of the bodies acting on that planet; or we have not interpreted aright the effect of known conditions. In the course of a truly logical treatment of the question, the latter alternative must first be examined: and this examination necessarily consists in a revision of the theory given by LAPLACE concerning the action of Saturn and Jupiter,—in the scrutiny of BOUVARD'S calculations,—and in the discussion of the Inquiry alluded to a short time since, viz: whether, by varying the normal Ellipse within the limits which confine it, and thereby altering the quantities which we ascribe to the deflecting influences of those two large Planets—the existing inconsistencies may not be made to disappear? It was indeed apparently a hopeless idea, that the skill of the author of the MECANIQUE CELESTE might here have failed, or the persevering sagacity of BODUVAR; but in presence of a difficulty so startling—of an anomaly so unmanageable amid the harmonies of our System—no weight of authority could be allowed to forbid our exploring every chance of error; and, accordingly, one of the great men, concerning whom I am to speak, devoted himself at the outset to the immense calculations necessary to construct again from their very foundations, the theory and tables of Uranus. In the work of both of his predecessors, LEVERRIER found room for modifications; and having effected these, he exhausted all possibilities of variation in regard of the normal ellipse. The difficulties were by this investigation, to some extent, diminished; but the startling anomaly remained in fullest force: so that every chance of mistake being banished, the fact stood forth as absolutely and unquestionably true—that there is *a formal incompatibility between the observed motions of Uranus and the hypothesis that he is acted on only by the Sun and known Planets, according to the Law of Universal Gravitation.*—I must here, once for all, solicit the expression of your admiration in respect of the immensity of the sheerest and most unmitigated toil, undergone in this great research. The final results of Astronomy are usually so dazzling that the mind of the rapt student easily goes in with the idea that the road leading to them is equally pleasant; a road through gardens—among flowers—and by running brooks! Alas! alas! it is a hard and most weary path—across a moor without a blossom! No Siberian steppe can be more arid than the sphere of these labors of LEVERRIER; nay, in every portion of Astronomy the labor of dry calculation has become so overpowering that the resources of Analysis have of late been perseveringly bestowed, on the discovery of modes of shortening and checking these processes,—as one of the most effective means of increasing our power. LEVERRIER was detained amid such calculations during the season of the year in which, as a first approximation had informed him, his Planet was pas-

ing rapidly from that position in the skies which alone, for a whole year would permit of its being seen. But he hurried nothing—shrank from nothing; he bore himself as the high philosopher, to whom *guesses* are nothing, unless verified; and he knew that in questions like these, it was only the compatibility of accurate results that could lead to Truth.

As we advance, we get rid of uncertainties. The problem is now reduced to a simple form; viz: *Can the anomaly be explained by the supposed action of a foreign and hitherto unknown body on Uranus?* Here, too, however, is choice of hypotheses. Is that foreign body a *new planet*, or is it a body connected with Uranus—*a satellite?* The latter idea was favored by some Astronomers; but on grounds worthy of no more attention than previous conjectures respecting the Comet. If Uranus was so disturbed by a satellite, that satellite must have been large, and therefore we ought to have seen it even at that remoteness; but what is of conclusive importance, the description of perturbations which alone could have been produced by a satellite, is not the one with which we are at present concerned. Those would be essentially oscillatory,—the satellite being now on one side of Uranus, and now on the other; and perturbations of that kind are not sufficient for the phenomenon before us. In so far as analogy goes, then, we are forced on the conception that the disturbing cause may be a Planet—yet unseen by the Telescope. This idea, I am perfectly aware, was not a novel one. In a world so busy as ours, and where knowledge, positive and fanciful, belief and idle conjecture, are mixed up and whirled together amid our common speech, in grotesque but inseparable union; it would indeed have been wonderful if this most natural assumption had been overlooked: but rather than seek amid so strange a chaos for the origin and indication of a grand verity, let us give the credit to the true workmen, to whose minds the conception was doubtless first recommended by its general verisimilitude, but who were moved thereby, only to work the thought through all its relations, to inquire—in due lealty to Nature—whether this conception was really consistent with her arrangements, and could, when fully carried out, explain the difficulty in its details? "THAT MAN ALONE DISCOVERS WHO PROVES." It is time the truth were apprehended, that there is no royal or easy road to Philosophy.

The Inquiry, then, points to a NEW PLANET. That word, often carelessly pronounced, became, in the hands of ADAMS and LEVERRIER alone—a definite and practical thought.

If a New Planet—WHERE? By the general order of our System, certain *a priori* grounds of approximation were afforded, which could hardly be much in error;—at all events, they greatly simplified the earliest calculations. *First*, it is a law among the known planets, that they lie nearly on the plane of the Sun's equator. Suppose, for illustration, the Sun represented by a ball laid on the middle of a table, then all the Planets would require, if represented, to be laid nearly on that table;—no one would be found far above or below it. The new Planet probably following that law, we should look for it in the Heavens only through that zone, whose center is the *Ecliptic*, or the annual apparent path of the Sun; nay, for conformity's sake, we may suppose that the planet is *in the Ecliptic*; for its utmost probable deviation from that line would produce no sensible error. *Secondly*, there is another remarkable law, whose origin is quite unknown, but whose authority, as far as the limits of the orbit of Uranus, was undoubted. It is this—Any planet—speaking in general terms—is half as far away from the Sun as the one next in order in ascending, and twice as remote as the one next in order in descending. If the distance of the EARTH, for instance, be represented by 1, the distance of MARS is 2, and that of VENUS ½; and so through all the known system. This law is sufficiently general to have been the cause of the discovery of that singular group of infinitessimal bodies between Mars and Jupiter—the progression having there indicated a *hiatus*, to be filled up by a new body; and that group—resembling the elements or fragments of a single planet—occupies almost the requisite orbit. It was no unjustifiable hypothesis, therefore, to extend this law to the planet now sought—especially as other although minor considerations sustained the conclusion regarding the body's probable distance. The question thus became as follows:

"Is it possible that the inequalities of Uranus are due to the action of a planet situated in the ecliptic, at a mean distance double that of Uranus? And if so, what is the place of the planet, what its mass, what the elements of the orbit through which it moves?"

It appears simple now: but assuredly this was the most daring effort ever undertaken by Man. The Earth is distant from the Sun almost by the enormous space of one hundred millions of miles. Uranus is nineteen times farther off, and this supposed planet must, by hypothesis, be yet twice as far! Can it be, then, that the thought of Man, as the faithful interpreter of Nature's Laws—sympathizing, as it were, with her universal designs—can walk safely amid profundites so dread, and evolve the necessary complements to our planetary Scheme? Are we bound so closely with the system to which we belong, that not a vibration can escape us? Is the human Mind indeed so indefeasibly coördinated, even with the grandest laws of this Universe?

I wish I could follow—with the hope of being accompanied by my hearers—the march of LEVERRIER and ADAMS, in the unwinding of this memorable problem: but their sagacity having for its essential or only possible garb, the symbols and processes of our most recondite Analysis, it is merely a few vague conceptions that I can expect to give of its character and elevation. In what I do say, I shall abide by the processes of LEVERRIER, partly because they are more susceptible of representation than the more general developments of Mr. ADAMS, and also because, as a matter of fact, they led to the first discovery of the actual existence of the body sought for, and therefore first proclaimed to the world this new triumph of Science.—There are a few, although only a few, distinct points, which may be generally apprehended.

It cannot require acquaintance with technical analysis to enable one to apprehend the nature of one means toward the solution of this problem, viz: the method adopted by Leverrier,—of *approximation*. A view of the conditions that must determine a final result of only a rough description, would evidently conduct to *limits* within which both the place and the mass of the planet must lie. After the different quantities involved are assorted according to their relations, it is not difficult to conceive how a view of their mode of arrangement would lead to the conclusion that—without attempting minuter appreciation—the attributes of this body must be confined within certain distinct numerical expressions; and that—as the two most important attributes—the *place* of the orb at a certain epoch, and its *mass*—might be roughly separated, the one having to do chiefly with the *direction* of the disturbing force, and the other solely with its *magnitude*,—it was no unlikely thing that a preliminary statement with regard to both could be made: which—being accepted—would

greatly facilitate farther inquiry. LEVERRIER's first conclusion was as follows:

"There is in the whole Ecliptic only one region in which the perturbing planet can be supposed to be placed, so that it account for the irregular movements of Uranus. On the first of January, 1800, its mean longitude must have been between 243° and 252°."

My hearers will readily appreciate the extent of new knowledge acquired by this step. By our first and fundamental assumption, the new planet had to be sought only in the Ecliptic—in that *one* great circle around the Heavens, and not indifferently, in any place of the dazzling vault. The meaning of the foregoing *numbers* is as follows: To fix or refer easily to the place of a star in the ecliptic, we suppose that whole circle divided into three hundred and sixty equal parts, named degrees; and we begin to reckon these from a determined point, viz. the first point of Aries—passing all round that great circle. Observe now the limitation previously made; the place of the unknown planet was confined by it *within the brief space of* NINE DEGREES, *in a circle consisting of* 360°.

This important limitation conducted immediately to a much more distant enunciation of the planet's place. LEVERRIER soon discerned that the necessity of satisfying all the relations of the unknown quantities would not permit an uncertainty as to the planet's place of even these nine degrees, and having determined the limits of its mass, he reached the following proposition:

"That all the observed motions of Uranus could be accounted for by the perturbing action of a planet, the elements of whose orbit were primarily assumed, whose longitude on 1st January, 1800, is 252°, and whose eccentricity and the longitude of its perihelion were determined by processes he had just explained."

The mass of the planet he had between the mass of Uranus, and one three and a half times as large.

From the previous theorem it followed that on the 1st of January, 1847, the heliocentric longitude of the required orb must be 325°;—an astonishing approximation, with which most men would have been satisfied; but it only informed LEVERRIER that a farther accuracy might yet be obtained!

On the 31st of August, 1846, LEVERRIER produced his last great paper to the Institute. During his former researches, or previous to his having selected any part of the ecliptic as more likely than the others to contain the new Planet, he had confined himself to consideration of a certain number of the facts ascertained in regard of Uranus—selected because of their fitness to yield a first approximation; but to give his work the utmost precision of which it was susceptible, he now employed the whole of the nineteen old observations made between 1690 and 1771, and a very large number of the two hundred and sixty-two places found in the records of the observations of Greenwich and Paris between 1781 and 1845;—each of these separate facts giving a distinct *equation of condition*, as it is termed, or a numerical value of certain combinations of the unknown quantities, viz, the correction of the elements of the orbit of Uranus; and the mass, and the elements of the orbit, of the Planet sought for. No fewer than *nine* unknown quantities were involved in this work; and he reduced his equations ultimately to the number of *thirty-three*. The treatment of these, again involved immense toil; and it was while undergoing this last labor that LEVERRIER had the mortification to observe that before his calculations could possibly close, the planet, in its apparent course through the sky, would have passed for the year from a position the most favorable for its being seen. His labors at length were terminated; and he announced finally to the French Academy the following elements:

Radius of the orbit,	36·154 times that of the Earth.
Period of revolution,	217 387 years.
Mean longitude, January 1, 1847,	318·47
Mass,	$\frac{1}{9300}$

From which, an easy computation showed, that the true heliocentric longitude on 1st January, 1847, must be

326° 32

instead of 325°

as roughly given by his first approximation. How singular that scene in the Academy! A young man, not yet at life's prime, speaking unfalteringly of the necessities of the most august Forms of Creation—passing onwards where eye never was, and placing his finger on that precise point of Space in which a grand Orb lay concealed; having been led to its lurking-place by his appreciation of those vast harmonies, which stamp the Universe with a consummate perfection! Never was there accomplished a nobler work, and never work more nobly done! It is the eminent characteristic of these labors of LEVERRIER, that at no moment did his faith ever waver: the majesty of the enterprise was equalled by the resolution and confidence of the Man. He trod those dark spaces as COLUMBUS bore himself amid the waste Ocean; even when there was no speck or shadow of aught substantial around the wide horizon—holding by his conviction in those grand verities, which are not the less real because above sense, and pushing onward toward his New World! (Great applause.)

We touch on the close of this long and noble endeavor, viz: the actual discovery of the Planet.—There are several points connected with this act, which it is of extreme importance that my readers rightly understand. The discovery of a planet by the telescope can be made only in one of two ways—by the observation of one of those two features which alone distinguish such a body from a fixed star, viz: its possession of a *palpable disc*, or its having *planetary motion*.

If the orb is of sufficient magnitude to exhibit a measurable disc to the telescope employed in the research, its discovery is comparatively easy; for the feature in question wholly separates it from the class of the Fixed Stars. These mighty orbs, although of the magnitude of Suns, are seated so profoundly in space, that to the largest instrument with which we have yet examined them, they appear with a brilliance augmented indeed in proportion to the size of the telescope, but still only as *points*, severed essentially from those small orbs whose dimensions we can descry and compare, and which are our companions and neighbors. It was this attribute which revealed Uranus to HERSCHEL; and LEVERRIER threw out the idea that the actual mass of Neptune, and the augmented power of the Instruments that can now be pressed into service of such a research, favored the expectation that, by its possession of a visible disc, and therefore without any overpowering labor, this new Planet would be found. In several parts of this remarkable work, Discovery seems to have been attended by a propitious chance; and although, as we shall afterward see, the grounds of LEVERRIER's expectations were here fallacious, his prediction of the actual *apparent* size of Neptune approached surprisingly to the truth. This disc, however, although definite and measurable, is so small as to be almost illusory; and it was not by it that the Planet was discerned.

Unaided by any visible disc, the Explorer has only one other resource: among the multitude of small stars in the quarter of the Heavens where

the unknown orb is conceived to lie, he requires to ascertain whether any one has a planetary motion. But this cannot be discerned by a single inspection. The motion at remotenesses like those with which we are now being conversant, must be so slow, that, for the brief time of one night, or even of several nights, it may be virtually equivalent to stillness; so that it cannot be detected save in one way, viz: the careful comparison of the state of the Heavens on one night, with their state on some other night, separated from the first by a considerable interval. Now, this comparison is not easily accomplished—nay, it involves great labor; it requires that *an accurate map* be made of all the small stars in the region of the sky under scrutiny, *at these two several times*; and to do this—to map the small stars in any region of the sky even once, involves a labor so great—taking the necessary exactitude into account—that LEVERRIER gladly expected the desired result from the visibility of a *disc*, and Fortune was again favorable!

For many years a great enterprise has been in the act of being performed by the Academy of Berlin—chiefly through the instigation of the illustrious BESSEL. Convinced of the great importance of the work, especially with regard to such discoveries as this—the Academy undertood the mapping—with all the precision which our modern Instrumets render possible—of the small stars along the entire *Zodiac*, or along that belt of the sky, where—from the analogy of the other parts of our system—new planets might be expected to be seen. The labor required to achieve this was enormous; and it was divided among a great number of persons, having requisite instruments. Now, it so happened that the map of that precise region where the new planet was expected, had been completed by Dr. BREMIKER; and it was printing, or just printed, at Berlin:—I believe that the Observatory of Berlin had obtained the proof-sheet. The Astronomers of this Institution were thus in a position of power regarding such inquiries, enjoyed by no other Observatory in existence: they had simply to notice BREMIKER'S Map and then the Sky—observing if there was a discrepancy between the two pictures, that could be accounted for by the planetary motion of some one star: so that—with their renowned sagacity, and the excellence of their instruments—an inspection of the Heavens on one clear night might accomplish the resolution of this great problem. And thus it even was; the Planet was discovered actually by M. GALLE, on the very evening of the day on which he received the letter of LEVERRIER indicating its place. (Applause.)

As ascertained by M. Galle, the heliocentric longitude of the body for the epoch of 1st January, 1847, would be

	327° 24
The predicted longitude	326 32

as before stated. The difference was, therefore, less than one degree or only fifty-two minutes!

I am, indeed, aware that few grand discoveries have ever been achieved without some degree of previous disappointment on the part of the discoverer. More or less enveloped in shadow they loom for years before his anxious eye, but the entire annals of Observation probably do not elsewhere exhibit so extraordinary a verification of any theoretical conjecture adventured on by the human spirit! M. LEVERRIER received the cheering intelligence after he had concluded his last paper to the Institute on the subject; and his bearing was too striking and characteristic to allow me to omit reference to it. "This success," says he, "permits us to hope that after thirty or forty years of observation on the new Planet, we may employ it, in its turn, for the discovery of the one following it in its order of distances from the Sun. Thus, at least, we should unhappily soon fall among bodies invisible by reason of their immense distance, but whose orbits might yet be traced in a succession of ages, with the greatest exactness, by the theory of Secular Inequalities." Verily, what a man is this! On hearing that he had done a deed unparalleled in scientific history—that to his thought of unexampled daring, even God's Starry Universe had responded, and in its own splendid and imperishable language pronounced its verification—not one reflex glance on himself, not a complacent smile on the isolated ME, which amid these infinitudes had been privileged to do a work, and therefore claimed and panted for its special homage, but a firm—a rejoicing and withal a reverential hope as to the progress of that Humanity, from participation with which his own strength will come—for the progress of that Human Spirit whose earthly destiny will not cease until, after the evolution of ages, that grand material imagery lies in all its mysterious gorgeousness prostrate as spoils at its feet. (Great applause.)

[Dr. NICHOL here closed his lecture, although he had to leave untouched several of the most interesting points relating to the discovery of the planet NEPTUNE.]

LECTURE IV.

Continuation of the history of the Discovery of the Planet NEPTUNE....The Discovery of the Planet not the result of Chance.

LADIES AND GENTMEMEN: I proceed with the great subject which occupied us the last evening. I confess, however, that some of the questions that are to engage us have to me less than their natural attraction, because I can hardly do what alone I wish, viz.: declare my opinions and knowledge concerning them, without undergoing the hazard of being considered as if in controversy with men on this side of the Atlantic, who do not think as I do, and whose learned and professional inquiries may have led them to conclusions not in harmony with those toward which we are inclined in Europe.—Let me, then, at the outset, with all possible distinctness, utterly disavow the attitude of controversy, as unsuitable, ungraceful on this platform. So soon as the important inquiries of which we are speaking have reached their close, and the Planet NEPTUNE is received as a thoroughly understood element of our Planetary System, with relations all fixed and definite, then whatever of specialty or incompleteness may have been in the views of any one during that period of imperfect knowledge or of twilight, will doubtless be explained, reconciled and amplified by its authors: at least, it is far from necessary that I, whose business it now is simply to unfold in language fitting our opportunity, the manner in which my own reflections have, in the meantime, presented to me a difficult and remarkable subject, should place myself in conflict with others, especially when the occasion is wholly unfavorable to a critical analysis of the grand causes of our difference.

With these preliminary and protective explanations, then, let us now pass freely and unembarrassed along our course. In my last Lecture I endeavored to bring my audience down to that point in the history at which the Telescope at Berlin verified the remarkable prediction of LEVERRIER—the point at which it was revealed that the simple power of thought—by carrying his fixed conviction in the perfectness of the harmonies of the Universe to its legitimate conclusion, he had laid his finger on the spot occupied by the orb he sought for, with an error equivalent only to about one and two-thirds the apparent diameter of the Sun.

LEVERRIER'S prediction was that at a certain time the planet would occupy a space indicated by the numbers 326° 31′, and the position it actually occupied when discovered was as follows: 327° 24′, constituting an error of less than one degree of space. [Applause.] Now, to give you an idea of the proximity with which the prediction corresponded with the fact, I will state that this space is just about one and two-thirds the apparent diameter of the Sun. This space, however, although small in appearance, is yet undoubtedly very large in quantity. It will be found, when reduced to miles, to be about 40 000,000. A very small space indeed, when seen from this enormous distance, the remoteness being so vast.

I need not inform you that since the discovery of NEPTUNE it has been watched with every sedulousness, in order that by an accuracy of measurement which Art now enables us to transport into these far spaces, its entire dimensions and the nature of its orbit might be known. I mentioned the last evening that from a small portion of any observed orbit the application of the law of Gravity enabled Astronomers to deduce the entire of it; and fortunately a happy discovery—made first, I believe, by an American Astronomer, Mr. Leart C. Walker, and about the same time, or very soon after, also, by an observer of Germany—greatly accelerated the period when, on the ground of fact, the leading features of NEPTUNE's orbit could be correctly deduced.

My hearers will remember that when exhibiting the extraordinary eccentricities of Herschel's orbit at the last Lecture, I mentioned that the orb had been seen before it was discovered to be a planet, and that these old observations were of great assistance in determining its perturbations. Now a happy accident of this kind occurred with regard to the planet NEPTUNE. The planet, it was found, had been seen twice by a Frenchman named LALANDE, in May, 1795; and this Astronomer so narrowly missed the honor of adding a fresh constituent to our system, that he rejected his observation of May 8, because it did not agree with that of May 10—thus losing the momentous truth he would immediately have reached, through inadequate *faith* in his observations If, instead of doubting his observations, he had watched the orb, he would have discovered the planet; but instead of doing so, just in one of those moments of carelessness that will occasionally come upon the most accurate and careful persons, he said, "One of my observations must be wrong, and I will blot it out," and so he did, and with it he blotted his own name from the scroll of immortality.

Although this observation was not, under the circumstances, extremely creditable to Lalande, it has been, as I have said, of the very highest consequence to us, for by extending the observed portion of the orbit over a very considerable space, it has enabled us even so early to reach with much certainty the leading facts connected with the motions of NEPTUNE—having revealed at once the true distance of the Planet, and its period of revolution. And *here* it is that the strange intelligence came to us which seemed to impair the beauties of those labors of ADAMS and LEVERRIER, which, according to an impression that in this country has become most prevalent—not only withdrawing from them all pretension to perfection, but even disentitling them to their assuredly just claim of having been the certain, the unerring means of discovering this New World, and indicating its place amid those remote infinitudes. The intelligence indeed was of a nature that could scarcely seem otherwise than startling, for it showed that in that part of their inquiries which attained the distance of NEPTUNE, according to BODE'S law, both of these great Astronomers were in error, and not by a trifle—a number small in relation to the kind of numbers we use in pursuance of such inquiries, but even by

a sixth part of the Planet's entire distance from the Sun—by the enormous space of six or seven hundred millions of miles ! !

I think the audience must remember that I said that when these two Astronomers began their investigations. they assumed two things : First, that the new orb would lie in the same plane with the other Planets ; and secondly, that according to BODE's law, it would be lying about twice as far away from the Sun as Uranus, which would make it thirty-eight times farther away from the Sun than the Earth is. Now it has been found to be only about thirty times as far from the Sun as the Earth. This shows us that throughout the whole of their calculations, this enormous error of distance extended. It is a very remarkable fact, certainly, that a law which prevails in so many instances should be found to fail in this particular instance. But it often happens when laws whose principle we do not understand are extended over a considerable space that they fail. Now the origin of BODE's law is entirely unknown: it is what is called an empirical law, because we do not understand the principle upon which it acts. The failure of BODE's law, however, was not the remarkable circumstance; the remarkable, the extroardinary circumstance was that, with this great error in their calculations, these Astronomers should have come to a true conclusion! The audience will observe that this error in the distance of the planet involved also an error in its revolution, for the revolution of an orb *depends upon its distance from the Sun.* While LEVERRIER and ADAMS supposed NEPTUNE revolved round the Sun in 217 years it actually goes round in about 166 years—making a difference of 51 years ! !

I cannot marvel that the announcement of this extraordinary and certainly unlooked for discrepancy threw over the whole inquiry an exceeding doubtfulness ; and this not merely in the current of popular opinion ; for the more thorough our knowledge of the perfection of the Celestial mechanism, the more perfectly we see that in the mighty sphere around us, where every atom is fixed and adjusted by eternal laws, and cannot in any way be altered in position without a corresponding change of its relations with whatever else exists, even the less likely did it appear that the supposed relations of a false planet with URANUS should have sufficed to conduct us so unerringly to the discovery of the actual orb.

[The Lecturer here drew several diagrams upon the blackboard for the purpose of illustrating the impossibilities of mere chance having aught to do in the discovery of NEPTUNE. The succeeding passage of the lecture contains a full statement of all the ideas illustrated upon the blackboard.]

The case is, no doubt. a strange one; but as nothing can happen within this scheme of ours without full and adequate cause, we proceed without desponding to endeavor to unravel the mystery.—And at the outset I would reiterate it as a truth beyond the reach of question—one which we must hold constantly in our thought, that two planets cannot possibly explain the same thing. The perturbations of Uranus which conducted to this great discovery. flow from one orb alone—the TRUE NEPTUNE, and not the false one ; and the latter cannot personate the former in regard of its actions within our System. The laws of the Universe are too fixed and definite to permit these personations and exchanges. Each atom in this immense fabric has its unchangeable and incommunicable place and functions ; nor can any individual put off or exchange his duties for the responsibilities of another.

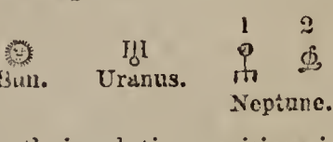
[The speaker here drew another diagram on the blackboard, for the purpose of enforcing still more strongly the ideas contained in the above section of his discourse, after which he continued :]

I am now done with preliminaries. You will perhaps excuse their tediousness, for I think you will see that we are dealing with what lies much out of the direction of ordinary thought, and which therefore it is not easy to clothe with a customary garb. My sole object is to accomplish this, and therefore I have hazarded apparent repetition, and have not regarded scientific forms of exposition and speech. (Applause)

Let me now remind my audience of the essential aim alike of ADAMS and LEVERRIER. It was, *to lead to the discovery of the disturbing planet—to lead I say to its discovery,* to point to that part of the Heavens where the telescope ought to find it—an aim grand and adventurous indeed—but which was essentially limited—(a fact, by-the-by, to which sufficient attention has not been drawn)—for they did not undertake wholly to produce NEPTUNE—to unfold through calculation, what afterward would be deduced from facts ; they sought for nothing except to indicate that part of the sky where the planet was now lurking, and where the telescope might detect it.

In beginning the solution of this remarkable problem, they assumed Neptune's distance, reposing with confidence on Bode's law. Now it appeared to many Astronomer's, English as well as foreign—looking at the question in an *a priori* manner—that this law might be inaccurate, and therefore that the solution had little chance of being a true one : and doubtless this very fear must have occurred alike to ADAMS and LEVERRIER ; but ere they had proceeded far with their work the most important truth came out that, at an epoch the most momentous of all, the two planets, Neptune and Uranus, held that precise relative position in regard of the Sun which rendered error in distance of no moment in respect of the new planet's place—the position where it affected their estimate of the planets mass only.

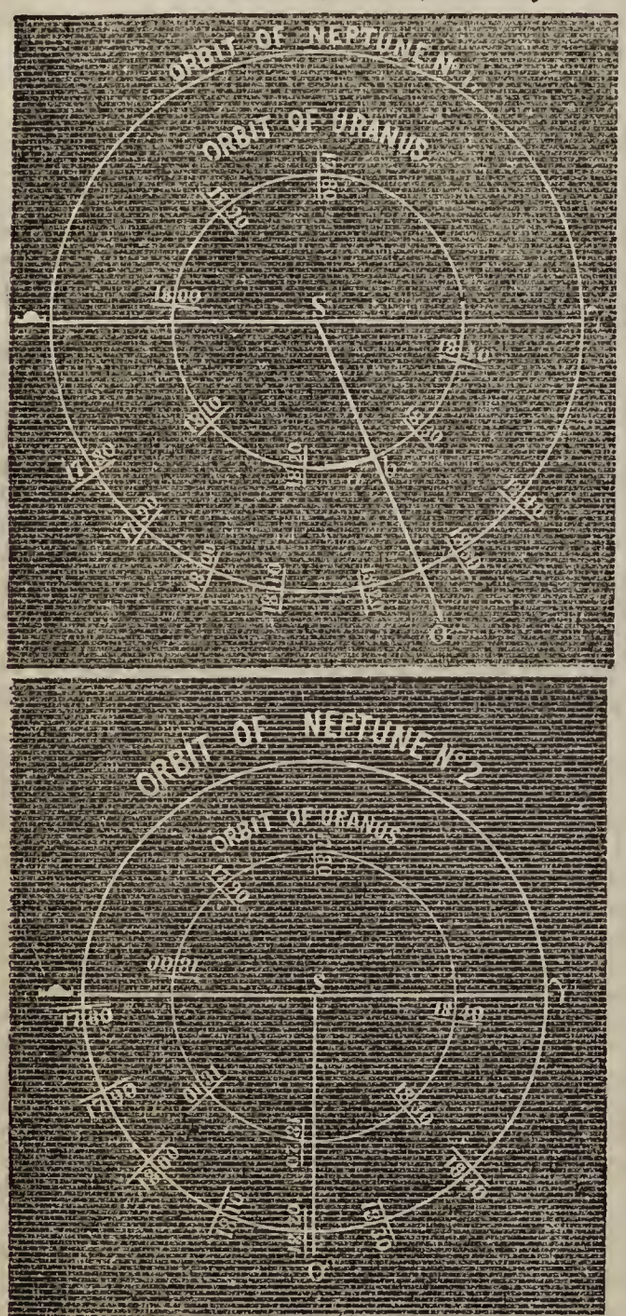
The following illustration will perhaps enable you more readily to grasp this idea. Suppose the Sun, Uranus and Neptune to be situated with respect to each other as represented below,



which were their relative positions in 1820. It will be apparent, at once, that it matters not what the distance of Neptune may be, whether it is situated at 1 or 2 ; the *kind* of influence it will exert over Uranus will be the same whatever its distance. To exercise a given degree of influence, however, the mass of the planet must increase as its distance increases, and *vice versa.* But farther, in a few years these orbs. 1 and 2. owing to the difference in their velocities. would be scattered—would occupy different positions in respect to Uranus ; when, of course. their influence upon that planet would cease to be similar in *kind*, that is, they would not be pulling Uranus in the same direction.

This fact. however. (the conjunction of the two planets in 1820) although perfectly adequate to explain the conformity of the two orbs. within the period bordering either side of 1820 will not, it is evident. extend much beyond that neighborhood—the different velocities of bodies at so very different distances would cause them soon to diverge—so that in 1846, when the discovery was actually

made, their positions in the sky would hold with each other no tolerable degree of proximity.



The above diagrams show the relative positions of the NEW PLANET and Uranus during the various periods at which we have obtained facts from observation—extending from 1780 to 1840. Now it will be noticed that excepting at or near conjunction—the point marked by the line drawn from the centre—the *relative positions* of the two Planets in respect of Uranus *do not egregiously differ:* throughout the course, the *kind* of the perturbation must be the same in either case, except in the brief part of the orbit, *a b*, fig. 1, marked by a thicker line, during Uranus' motion, in which the bearing of the inequality would in the two cases be opposite. This would certainly be the case if the orbit of the planet were *circular*, as I have represented; but it may be easily supposed. that by the adoption of an *elliptical* or *oval*, instead of a *circular* orbit, this cause of discrepancy might be made to disappear, simply by effecting the transfer of the point of conjunction in the case of fig. 1, to a point corresponding with the true epoch, as represented in fig. 2.

[The lecturer here had recourse again to the blackboard, on which he exhibited and illustrated in various ways the conjunctions, accelerations, and retardations of Uranus occasioned by the TRUE and FALSE planets—the orbit of the TRUE planet being represented in fig. 2, while that of the FALSE planet is represented in fig. 1; he also represented the difference between two classes of perturbations, the first class called Periodic inequalities, which refer exclusively to *direction*,—the second class called Secular inequalities, which relate exclusively to distance. All these things he made to appear very simple by means of his diagram, but we cannot present them to our readers inasmuch as we were unable to report the Professor's *blackboard.* In conclusion he said :]

It seemed to me to require this additional explanation to give to the view of the subject I desired to address to you its due completeness, and to entitle me to assert that in all respects the labors of the illustrious men whose footsteps we have been tracing, come forth rounded and beautiful, characterized by the loftiest powers, for which are yet in store even nobler triumphs. Neither, perhaps, was it wholly unneedful in vindication of Man's existing knowledge of our System's Mechanism. Facts—the facts requisite to enable us to apply theories, cannot of course be hastened on —we must wait and watch as the ages unroll themselves; but in respect of our ability to understand them when attained—I cannot now discern a term. It is not possible that in this place I can demonstrate or confirm it, but yet in confidence I allege that a time is not far distant when we shall be able to extend, as it were, a great chart through our System, on which every orb belonging to it will leave an impress of its relations as clear to the skilled eye, as the fine mechanism of a leaf to the microscope of the Botanist; ay, building on these proud labors of ours—it may be, as time shall pass. that with hand as firm among those grand Stellar Systems, having unrolled their order, we shall stretch there too even such a plan and chart—to which the throbbings of these entire Starry Universes shall report themselves, and where they will impress their harmonies for the inspection of Man! (Great applause.)

LECTURE V.

The PHYSICAL CONSTITUTION of our System....Discussion concerning the nature of Comets....Their motions ....Their subjection to gravity....Their immense periods....Strange phenomena presented by Halley's Comet.... The idea of POLARITY, and its application to such phenomena....Probable universality of its developments among material phenomena.

LADIES AND GENTLEMEN: I have now endeavored to explain and fully to exemplify by means of the remarkable discoveries of the planet NEPTUNE, the nature of the mechanism that sustains our Planetary System. As we have seen it, it indeed appears most compact and harmonious—every orb bound to all others around it by sympathies which seem indissoluble, and which raise the smallest atom from a condition of isolation into a constituent and essential part of the vast fabric. An understanding of this mechanism, so full and minute as that which, under the guidance of ADAMS and LEVERRIER, has enabled us to penetrate with so sure an effort to the far region of NEPTUNE, may well be considered at first sight almost to have exhausted all problems of interest connected with our System; but inasmuch as Man's knowledge never is nor can be complete—inasmuch as it is his destiny always to struggle, and his hope ever to rise—we have no sooner reached what seems satisfactory in this line of inquiry, than doubts and difficulties press for notice which lead to investigations yet loftier and farther reaching. It soon occurs to us, on contemplating this mechanism of ours, that although the law of gravitation entirely explains how it at present proceeds, enabling us to trace the many and complex relations of all these orbs, there still are facts connected with it, and these of high import, which the simple action of gravity as the sustaining power does not explain.

Nothing, I think, could convince one more surely than the discovery of NEPTUNE how completely we have got hold of the laws governing the internal mechanism of our system.

I mentioned on a previous evening, for instance, that we find all the planets *lying nearly in the same plane;* to illustrate: suppose I place a ball in the center of this table; now let the ball represent the Sun, and then if I were to represent the position of the planets by other balls, I would have to place them on the table also, and not *above* nor *below* the surface of the table. Now the law of gravity does not explain this. It would sustain the motions of the planets round the Sun, however lying in space.

I also stated that the curve described by an orb revolving round the Sun is an ellipse, not an oval, and that gravity would sustain a planet moving in any ellipse whatever, but we find that these orbs are all moving in an ellipse very near a circle, so near that unless you represent the orbit on a very large scale you may represent it by a circle. Here, then, is another condition which the law of gravitation does not explain.

Thirdly: We find that the planets are all revolving round the Sun in one direction. We do not find one traveling in one direction and another pursuing an opposite course, but all sweeping round in the same direction. This also is quite unexplained by the law of gravitation. They might move in any direction and still gravity would sustain them.

Fourthly: We find that the Satellites move round the primary planets in the same direction that the primary planets revolve round the Sun. Now when we consider the number of the primary planets, this may be regarded as a special arrangement, and one not at all accounted for by the law of gravity.

Lastly: The planets and satellites have a rotary motion on their axes, as also has the Sun, which completes its revolution in twenty-five days, and all these motions take place in the same direction. This is not explained by the gravitating power.

Now when persons look at these facts it must strike them that there is some great law here which gravitation does not explain. I should mention, by-the-by, that to the circumstances of which I have spoken there is one exception. The planet Uranus has three satellites. Herchel said it had six, but no other Astronomer has ever been able to discern more than three. Lord Rosse's great telescope has never been turned to Uranus, and the question still remains unsettled, but we know that the planet has three Satellites. Now in this orb is the exception. Its satellites are not moving round Uranus in the plane to which the other planets are confined. They sweep out from it, nor do they move in the same direction as the other planets, but in the opposite. They move backward. Now this is the sole exception in the whole system to the order and the laws to which I have referred. The planet Neptune confirms this order. We now know that Neptune has one satellite, and its motion is the same as that of all the rest of the planets. I believe it may almost be said with confidence that Neptune has two satellites. A second one, it is said, has been discovered by the excellent telescope at the observatory at Harvard University, but it has not yet been satisfactorily ascertained.

The only exception, then, is Uranus, and the question arises, What are we to do with it? Are we to accept this single exception as overthrowing the general order? or as arising from some external cause with which we are not acquainted? I believe if you consider the vast number of other motions governed by the law to which I have referred, you must consider the case of Uranus as an exception. If we had not treated the Comets so lightly the other night I would say that a Comet would be very acceptable here. [Laughter and applause.]

That these facts are constituent elements of our System is not rendered necessary by what I have termed the sustaining power of Gravity, is sufficiently manifested by the phenomena of Comets, for these wandering mists pass round the Sun in all directions and in the most elongated orbits, defying every one of those laws which control the motions of ordinary planets. Instead of being confined to the plane traversed by the other orbs, they often come moving up toward the Sun from all quarters of the heavens. Instead of moving in orbits nearly circular, there is no ellipse so elongated that we do not find Comets moving in it; nay, we find them

moving in orbits called parabola and hyperbola; that is, in ellipses carried out indefinitely. Comets moving in such orbits visit our system but once, and then plunging into the boundless confines of Space are never more seen by Man.

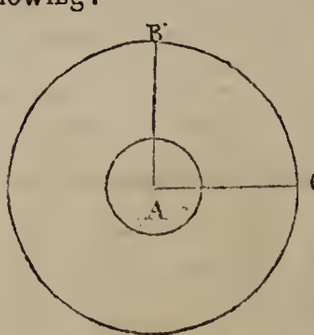
We know of several ellipses of immense extension. Halley's Comet has a very elongated one, stretching beyond the orbit of far-off Neptune, but even that is near us compared with the orbits of others we are able with great probability to conjecture. The great Comet of 1811—I presume many of my audience remember it—regarded as the most brilliant body that ever appeared in our heavens, and answering to the most terrific descriptions of the Comets given by the ancients, seems to have an orbit so immense that its period is about 3,000 years. To what an awful depth in space that body must go no eye but that of Omniscience can ever discern, and yet there is another whose orbit appears double that of the Comet of 1811, its period being about 7,000 years.

The facts to which I have alluded, then, must be held as especially characterizing the Planetary System—setting it apart as a distinct and peculiar arrangement, and no more flowing necessarily from the connection of Gravity than the forms sustained by the agency of life are sustained by the energy that keeps them in being. Indeed, this illustration is not inapt; for even as Life diffuses warming and glowing activity through the whole innumerable families of organization, so may this system of ours be but one exhibition of what gravity can perform—one special planetary arrangement, belonging only to one special class, among the immense varieties which must roll around those myriads of single, double, and more complex stars.

Accepting, then, the circumstances that I have described, as indications of the fundamental constitution of our system, the question arises, whence came they? What new knowledge concerning the Universe do they communicate? It may, indeed, not unnaturally occur, that questions like these are in their nature unanswerable; that they resemble the inquiry, why is man's frame constituted as it is; and that the only answer of which they are susceptible, lies in the statement, "Thus was formed our system—thus fearfully and wonderfully was it made." That singular collocation, it may be said, is inexplicable, because the planetary scheme existed simply as it now is, and with these arrangements as its constitution, was launched into the domain of space by the immediate and direct fiat of the Almighty. This, perhaps, is the most natural explanation of these circumstances one is apt to give; namely, that the system exists as it does because God has made it so to exist. Now toward that most dread of all mysteries—either the time when or the mode how—these arrays of finite forms were projected from Himself by the unchangable Mind, I feel that I dare not approach, and I would venture to express it with all reverence, that such an endeavor—one so utterly unfitted for the highest powers of Man, is imperatively forbidden by all philosophy. Placed by the Eternal in the midst of His gorgeous material Universe, we are endowed with the most glorious privilege to look on Himself as mirrored there by the manner of His high-workings; but upon the intellect wherewith we must interpret these workings, He has laid conditions that it must obey. Now one of the most indispensable of these conditions is, that unless in cases where through a supension of the Natural Laws and other undeniable tokens, the great Parent should choose to make manifest His desire and declare directly concerning His purposes, we are bound by the necessities of our being to search forth explanation of every physical part through its relations with actual causes present or past—It is not given us to hope anywhere, or to say that we have known all; around us on every side is the unfathomable, and the farther knowledge increases the larger only grows that circle of darkness which bounds its light. (Applause.)

I would not be understood to say there was no beginning. Most undoubtedly there was—though removed from us by infinite ages that have rolled away—such a period; but to that period man by means of the faculties he now has cannot certainly go back. Our knowledge of the Solar System, with its characteristics, seems to me something like this: If you present a blossom to the insect called the Ephemera—which is born and dies within the hour—if that creature could look understandingly upon that blossom, it could say thus was the blossom made; but as to the changes which brought that blossom into existence, it could divine nothing. It could not reach the truth that the blossom is the result of growth. Just so the Solar System lies before the human mind. We see an external constitution, and we are led to say with the Ephemera, and with conclusion as legitimate, thus and thus the system was made. We are, therefore, I say, bound to look upon that mere arrangement as a circumstance which we must attempt to explain—whose origin we must attempt to discover in the mode by which the Solar System arose out of a prior system of being. In all parts of Physical Science the opposite course has been maintained. Men have said, here you must stop. Inquiry may not be extended farther than this. But I think it is the experience of all philosophy, that in every instance the barriers which have been thrown up along the highway of Science by bigotry and timidity have been broken down. As far, indeed, as man sees amid this august immensity, there is no resting place—no barrier that he cannot pass. A traveler bold and free, amid a region thronged with mighty mountains, he discerns before him range behind range in majestic prospective, rising until vision cannot pursue them, and they have hid their summits within the clouds and mists of the horizon; but *there*, as his heart feels full well—even *there* is concealment only and no termination; and ever and anon, as the ages roll, that white cloud parts like the unfolding of a royal gate, and lo! through the opening, some noble peak never seen by mortal eye, its top burning in the Sun!—(Applause.)

Again, pursuing inquiries touching Cosmogony, persons find many contradictions between their results and the results of the investigations of other individuals, these contradictions have always been brought forward and insisted upon as the ground for stopping inquiry in this direction. Now it seems to me that we are never in a position to decide when results do actually contradict one another. The state in which Man seems to me to be placed in relation to all inquiries of this sort is the following:



Man is here placed in a center [A] of some sort, & knowledge is stretching out all around him. Now within the compass of the small circle only, as represented in this diagram, is his knowledge complete—within that circle alone he is able to reconcile all the different phenomena that present themselves, and if he goes beyond that circle he will find a totally different condition. Now some bold inquirer, not satisfied with this limited range,

steps out of the circle of clear and distinct knowledge, and pushes up to B, where he discovers a portion of truth, and he unfolds it. Another bold inquirer strikes out in a transverse direction, and pushes out to C, where he discovers a small portion of truth—or at least of what he thinks is truth—also; but upon comparison, our two inquirers discover that their results do not and will not harmonize. One cannot understand what the other has seen, and, forgetting that the vast space lying between the two points of discovery, and which serves to connect them, still remains unexplored, one says to his fellow laborer, "you must throw away your fancied truth—it is an error, it is heresy." The complaint of course, is immediately returned from the other side of the house, and they go on hurling their denunciations at each other, 'till time, at length shows them that their conduct is equally irrational on both sides. (Applause.)

The sum of the matter, then seems to be this—and assuredly it ought never to be severed from the inquirer's mind: that now we see only a part—that as in the moral world, even in the widest views of it upon earth, there are many puzzling and painful contradictions. So in regard of that Mighty Unknown which environs all our light. We have distinct views only by snatches, views of parts only—between which and our other conquests, persistent darkness, notwithstanding our most most vigorous efforts, continues to reign; and therefore, while holding on in fullest confidence and faith never wavering, that we must place the solution of all difficulties in the one case and the entire completion of knowledge in the other, among the hoped-for acquisitions belonging to those immense periods and serene realms which lie boyond the grave. (Applause.)

Having thus endeavored to clear our ground, so that no hidden scruple or reluctance shall interfere with our advance in the course before us—I ask again whence those remarkable constituents of our Planetary System? From what prior condition, so that it obtain those constituents, must we imagine it evolved? Bold inquiry truly for man to approach—but remember our illustration of the Ephemera! Remember how august the processes we shall dare to contemplate, or awful the depths of Time through which we shall track this growing order—we must compare them never with Man's acts or life—they are the ordinances of One who holds even the mountains in the hollow of His hand, and before whose everlasting endurance the entire life time of the Human Race is only a tick of the clock which is heard and past forever! (Applause.)

The circumstance over which I am now to conduct my hearers is the most sublime in the whole range of Astronomy, and is owing to the illustrious LAPLACE, who, perhaps, possessed a more profound knowledge of the laws, structure, and mechanism of our System than any other save NEWTON. LAPLACE, upon observing all of the orbs lying in the same plain, moving in circles, sweeping round the Sun in the same direction, and next, that the satellites observed the same directions, and finally, that the rotations of all the orbs proceeded in the same direction, at once said: "This circumstance cannot be solved by gravitation; and there is only one mode by which it can be solved, and that is by tracing our scheme from its commencement through all its various stages of development up to this time." This is not an unusual thing in Science.—Geologists do not think they are doing an illegitimate thing when they go back to the origin of our Earth and trace it from a liquid form to its solid state. LAPLACE went a step farther from this.—He said: "It is not improbable that all these orbs came into existence from a *gaseous* state, passing from the *gaseous* to the *liquid*, and from the liquid to the solid state."

"Let it be supposed then," he said, "that this great scheme of ours arose from the solidification and gradual congregation of an immense Nebulous mass existing in the aëriform or gaseous state."

We know that matter does exist in this form.—The Comets are gaseous bodies, and that immense quantities of gaseous matter exists, is the most important lesson that they teach us. As many as a million of Comets have visited our System, and this is few compared to the entire number that exist, therefore LAPLACE'S supposition is not improbable.

"Let us suppose," said LAPLACE, "in the first place, that our system arose from the solidification of an immense Nebulous mass existing in a gaseous state."

"Then," he said, "secondly: In what condition must we suppose that Nebulous mass to have been at the outset?" On looking at our Scheme he said, "The most general fact that we can predicate in respect of it is *revolution*. It seems to be turning round some great center." "Then," said LAPLACE, "we can attribute to this Nebula motion of rotation It must be turning round a center like a great whirlpool or whirlwind with a comparatively slow motion." The audience will perceive that these are two great hypotheses, but we must begin with hypotheses. No calculation or deduction can ever enable the human race to trace back our System to its origin. This being the case I would have the audience observe that LAPLACE'S system rests entirely upon hypothesis. It is a hypothetical Cosmogony.

Fancy, then, this great obscure chaotic mass existing of old amid the void, even where our superb System unfolds its glories—agitated by some motion which approached to a definite rotation; now, quitting all hypothesis, let us apply to it the supervision of Law and endeavor to follow its destinies.

All that is hypothetical I have already mentioned. What follows, is the application of known mechanical laws.

Let us now imagine an immense Nebular mass from which our System sprung, situated in space, with all its parts gradually drawing toward a center. You recollect we supposed this mass originally to be moving round that center with a motion extremely slow: What will result from this motion of rotation in consequence of the condensation of the Nebula? This follows. Ever as the Nebula condenses, the motion of rotation will become quicker and quicker, and finally will present itself under the aspect of a very definite and majestic phenomenon. I think the audience will see that this will be the case. The entire mass is supposed to be turning round all the while, and the particles moving toward the center at the same time. Now it is obvious that a particle at the circumference of this mass will move much more swiftly than one at the centre, and when a particle from the circumference goes down to the center, as is continually happening, it attaches itself to a center particle and of course communicates to the particle so attached a portion of its velocity, which must inevitably increase the rapidity of the particle at the center. This may seem abstruse but there are plenty of phenomena in every-day life to illustrate it. We will take the pendulum to a clock for instance. Suppose the clock moves too slow, what do you do? Shorten the pendulum of course. Now it is this very principle that will cause what I have been describing. It will be seen then that as this matter draws itself toward the center its motion becomes swifter, and that the body formed will have a rotation upon its axis.

Thus the great fact of the Sun's rotation is neces-

sarily inherent in our hypothesis, but does the hypothesis contain what seems far more difficult to conceive—the origin of these planets. So far we have spoken of nothing but this huge mass—no planets. Let us see if in accordance with a clear and distinct law, planets can arise from this mass. What gives the outer portion of this Nebula any connection with the center of the mass? Every particle on the outside of this Nebulous mass is acted on by two tendencies precisely similar to those which regulate the motions of the planets round the Sun; first, its tendency to fly away in consequence of its motion, and secondly, the attraction exerted over it by the whole mass which counteracts this center-flying tendency. Suppose however that one of these tendencies increases while the other does not. Suppose, for instance, that the tendency of the outer portion to fly away increases while the attractive power remains the same: what will take place? A separation of the mass, undoubtedly.—We know that the matter all around us upon the Earth is not homogeneous. There are varieties in it. We would naturally suppose therefore that the Nebulous mass out of which these orbs are passing would exhibit the same varieties of matter. If this were the case at intervals, the least condensive portions would gradually accumulate at the outer part of the Nebula. Suppose this to have been done then, so that at the outer portion of this Nebula there is a quantity of matter not so easily condensed as that occupying the inner portion. Now this inner portion would go on condensing more and more rapidly, and in consequence of this condensation the outer portion of the Nebula would be moving more swiftly, the equilibrium would be broken, the power drawing the outer part toward the center would not be so great as its tendency to fly away. There would then occur a separation between the outer portion of this mass—it would spread into a kind of ring standing by itself. This also may be illustrated by a common occurrence. For instance, sometimes when a grindstone is turned with too great velocity the outer part of it flies off. Now if this outer portion had not been solid stone it would not have broken. Had it been a band of caoutchouc for example, it would have stood out, a ring.—Now this would be precisely similar to the action of the mass to which I have referred. There would then occur, during the condensation of this Nebula, if it were not composed of homogeneous matters, ever and anon a throwing off of a ring which would lie out by itself in space. We here, therefore, have an idea how dependent matter would arise in the condensation. Indeed the ultimate state into which this condensation might bring this Nebula would be as follows:

We would have a large orb in the center, and at different distances in space apart from it, there would have been thrown off from it these dependent rings, turning round the central mass of course with the velocity with which the whole mass turned when they were thrown off. We thus have, as our first step, a great central orb and dependent rings lying out from it entirely in space. Now, before proceeding farther—before inquiring what forms of matter might probably spring from these rings, I would solicit my audience to observe what already we are able to deduce.

We can draw two inferences. Whatever the forms of these rings, they must be lying in the same plane. Then again observe another fact. The rings, as I have stated already, are found necessarily turning round the Sun with the velocity they had when thrown off, and they must all turn in the same direction. Then again, whatever is to come of these rings—whatever shape they assume. the great chance is that this kind of matter will turn round the central mass almost in circles. Now, then, observe as far as we have yet gone, the most important of these constituent points have been explained:

First—That all the planets are lying in the same plane.

Secondly—They are all turning in the same direction.

Thirdly—Their orbits are nearly circles.

As we proceed, the problem is manifestly becoming simplified—we are rapidly absorbing within one hypothesis all that seemed previously unintelligible. Let us advance with equal caution another step, and ask what is likely to become of those rings? In what manner will their particles ultimately arrange themselves? Now, first: if the ring, when it was thrown off, had been homogeneous and of the same thickness, or if during its subsequent changes, had been subjected to no foreign influence, the ring would *solidify and remain as a ring;* but if it were not homogeneous, and of the same thickness, or if it had been subjected to foreign influence, in consequence of its not being uniform the power of attraction prevailing in itself would break it up. Now, it is possible—although extremely improbable—that the ring would solidify and remain permanently as a ring in space. We might, therefore, considering the great number of bodies in our System, expect to find some one f them accompanied by such a formation, and sur enough we have one instance of the whole matter solidifying itself and remaining fixed in the heavens, a ring. Saturn furnishes us with this instance, which is the only one in our System. It has been said that Neptune has a ring, but I think a delusion has existed in this regard. It was formerly supposed that Uranus had rings, but it is now known that such is not the fact. In all probability, then, the ring upon Saturn is the only one in our System. I beg the audience to remember what I said concerning this matter. I said such a formation was possible but *highly uncertain;* and the bringing this ring into our System is a confirmation of our theory. When we are able to summon forth such formations to explain what is called an anomaly or a monster. we may be pretty sure that we are arriving at the truth. They stand out as finger posts to direct the attention to the investigation of the causes that produced them. (Applause.)

Secondly: Suppose the ring not to be uniform, as is by far the most likely to be the case. Suppose, for instance, that it had in different parts of it denser portions than in other parts, then the result would be this: Around these denser portions the whole matter would, ultimately, congregate.—It would cease to be a ring, and by the greater attraction of these denser parts the matter of the ring would be drawn around them. Now suppose these denser portions were scattered through the ring in such a way that their attractions would exactly balance each other. If the points acted so as to produce equilibrium. the ring would be broken up into a number of bodies, and they would appear as a number of small orbs revolving around the Sun at nearly the same distance. Accordingly, just as with the ring of Saturn, we have also one instance in our System of just such a result as this, viz: that group of small planets lying between Mars and Jupiter, all revolving in nearly the same orbit. We formerly supposed there were but four of these Asteroides; now, however, we know there are eight, and there may be more. Thus you perceive we have drawn into our System order out of disorder.

The third mode in which the ring might resolve itself is by far the most probable; it would condense and split up but the parts into which it would,

in that case, be divided would not balance each other, but one part would be greater than the others and the large part would absorb all the others so that the main result would be the breaking up of the rings into separate large planets. These planets would in the course of their condensation in order to form solid bodies, as it were, pass through something of the same course as the original mass, throwing off satellites characterized by the same conditions as themselves. Here then you see the Nebular hypothesis has given us an entire account of the structure of our system and the characters of the bodies of which it is composed. Another thing alone remains, viz; the rotation of the bodies upon their axes. This point I think my audience will readily apprehend. The question is, how does it happen that these bodies are moving round their orbits? Let us go back to the original Nebular mass. It will be remembered that the particles of the inner portions of the mass are not moving as fast as the particles of the outer portions, so that the instant the mass is broken, the stronger action of the outer portion would prevail over the velocity of the particles of the inner portion and cause the bodies to go round just in the same direction as the orb moves in its orbit. This, also, is illustrated by the most common things. Suppose for instance, that in the case of the fracture of the grindstone referred to, we observe the portions as they fly off. We would find that the fragments would turn round in the air in the same direction as the grindstone itself turns. This, then, is the last of the conditions to which I have referred; and it receives, I hope, a complete and satisfactory explanation from this hypothesis of Laplace. We have now a reason why our system presents itself not as an original, created and finished scheme, but as growing from a previous state.

How strange the thoughts with which in presence of the speculation I have now endeavored to unfold, we must gaze on the brilliant skies!—even that gorgeous jewelry of midnight, a birth—a thing of yesterday—a step in the awful march of those visible picturings of the purpose of the Eternal Spirit! Realize, in illustration, for one moment, the position of the tenant of a hut on the banks of the mighty Amazon at one of its great bendings; tell him that the waters whose opposite bank his vision can scarce reach, are not an immense lake with appointed boundaries, but that born of rills among moutains that are unseen and ever increasing in depth and potency, they have rolled downward until a whole continent is passed, and then mingle and lose themselves with an ocean engirdling the wide earth with its everlasting waves; so in the view of these high cosmogonies, seem to roll on those gorgeous Stellar Developments, whose limits no eye can now see—sinking among the vast depths of time, in some hidden purpose of God—rolling onward as the ages flow, and augmenting, like the mighty river, until the boundary of Time is reached, and their course ends among the Quietudes of Eternity. (Great applause.)

One farther point only we require to establish, ere this similitude be complete. As the great System before us had a birth and a progress—a growth toward its present glory—can we stretch onward our gaze toward a time when its strength shall wane—toward the closing scenes of these stupendous arrangements!

Even so, this Nebular hypothesis leads us to a glimpse of this change, it carries us onward to the time when our system shall cease to exist as it is, and pass into some other form of being. The circumstances attending this change appear to be the following. Recollect the two influences that keep the planets in their places. Suppose anything should operate upon Jupiter to retard its progress and diminish its centrifugal force. It would necessarily be drawn into the Sun. Now the tendency of Jupiter or any other planet to fly away from the Sun might be constantly retarded by some such action as this. Suppose that these planetary spaces are not void, but filled with ether, the matter out of which these bodies sprung. However light, the fact that all the planets are required to move through that ether must subject them to constant retardations. If, then, this ether exists throughout these planetary spaces, every planet moving through it must be subjected to its resisting power, and as the orb cannot put forth any vital power to overcome it, it must continue for ages and ages to retard its motion. Now the retardation of the motion diminishes the planet's tendency to fly away from the Sun, and, consequently, the attraction of the Sun will cause it constantly to approach nearer and nearer that orb, till it last it will be absorbed by it. Now, it might be supposed, that if this ether exists, we should with our fine instruments discern its effects precisely in this connection, and that we should discern how much it retards the planets—how much in every revolution the planet is drawing nearer and nearer to the Sun. But alas! the planets are by far too heavy to be subject to a perceptible retardation by so subtle an agent. What the planets have not enabled us to accomplish, however, has been done by means of a Comet. It was accomplished by the Comet of ENCKE, which revolves round our Sun in three years, passing through the orbits of some of our planets. Now the Comet and the planet stand in relation to each other in this wise: Take a piece of metal and a feather; drop them; the metal falls at once to the ground—it meets with no perceptible retardation; but the feather moves about in the air, seeming as though it would never reach the ground. Thus the feather shows us what the metal would not—that if one suffers retardation so must the other, although too small to be appreciated. ENCKE's Comet is the feather, and the planet's the metal.—Thus the Comet has demonstrated this fact so that Astronomers acknowledge it; viz; That there is a planetary ether filling the spaces between the orbs of our System, Every time this Comet returns it is retarded about two days, so that, in time, it will entirely disappear. Now the influence exerted upon this Comet must befal the planets, and though ages so vast must roll on that one may call them infinite, these solid orbs must be retarded, drawn nearer and nearer to the center of the System and thus our vast planetary scheme pass into another mode of being.

Thus the Nebular hypothesis shows us, not only the origin of our system, but carries us onwards to the time when it shall undergo some great organic change. This will not take place, however, as was supposed in the earlier stages of Astronomy, by violence. It was once supposed that the perturbations of the planets, would grow so large as to interfere with the order of the system. But this is not so. The perturbations exactly balance each other, and from this source nothing like confusion or ruin can ensue. Neither will there be confusion from that which I have just unfolded. Not in confusion shall this magnificent scheme finally pass away, not with the jar and confused voice of ruin but even in its own quiet and majestical order, like the flower, which having adorned a speck of earth lets drop its leaves when its work is done, and falls back obediently upon its mother's bosom! (Applause.)

It may still be in the recollection of some of my hearers, that I presented in our second lecture an exhibition of the nature of the activities prevailing

through all these Stellar Hosts—how, wherever such orbs are, *there* is change—immense motions accomplishing majestic purposes—all things rushing on toward some new condition—proclaiming that evolution, ceaseless and irresistible—advancing from the imperfect to the perfect is the Law of the Universe. That, indeed, was a noble spectacle—myriads of Suns in gorgeous arrangement marching onward, each on its great way, pointing toward regions far beyond the sight; but with a significance how much more profound is this same lofty truth when once more declared. The development of which I there spoke, was only an alteration in internal distribution of groups of stars, producing a change and gradual perfecting or simplifying of external form: but now we discern the orbs themselves rising, enduring, and then melting away; even these most stupendous manifestations of a material organization undergoing in their inmost structure the doom of mutability, bowing before that profound Law which persists or eminently endures as the cause and substratum of all change! How overwhelming must be those purposes whose greatness even these Heavens are not adequate to represent—whose amplitude, even these unfathomable depths cannot contain—of whose purity and expanse that whole Universe of stars is fitted to be an emblem only so transient!

There, a mere speck in the void, yet of itself so complex, so perfect, so grand, floats that Solar System of which our varied and beauteous world is but a minor part—it is but as a blossom fitted for a moment only to unfold itself and live, as the seasons of the august Universe pass. What, then, is this scheme as a whole?—where its beginning?—where its end?—and what the solemn Forms of which these existing splendors are but the early and imperfect rudiments? Questions, indeed, most vain! never, it may be, to be resolved by any whose tenement is in the flesh! And yet not vain in this. They seem to tell of that light which shall pour through the opening of yonder portals—shadows cast toward Earth by Alpine heights of thought—inaccessible now, but into whose presence anon, as a reverent child, the soul shall come, at that dread but not fearful moment, when, amid the crash of worlds, the meaning of the Phantasma shall all be revealed—the awful vail being rent in twain.

LECTURE VI.

Constitution of the PLANETS rapidly reviewed....Constitution of the MOON....Prevalence there of the cause which has upheaved our Earth's surface....Universality of this cause....Its nature, as indicated by the aspect of the Moon, not comprehended within current geological theories....Its tremendous craters or caverns....What gave existence to these?....Speculations as to this force....Two opposite views of it....Digression concerning meteoric stones....Progress of this grand cause of upheaval....Possibility of a relation between it and the apparition of the organic families on the surface of the Earth.

LADIES AND GENTLEMEN: I now proceed with you to the last portion of those contemplations which I desired to bring under your notice. We have spoken of the general structure and apparent destinies alike of the remote heavens and of our own Planetary Scheme; and I wish now to offer you a few thoughts on such details in regard of the constitution of our Companion Orbs, as more especially manifest their connection, as derived, probably, from a common origin.

Notwithstanding the memorable power of the Telescope, the information we have obtained in regard to the internal constitutions of the planets, is indeed singularly scant. I am not sure, indeed, that we can venture to state farther in regard of them than two very general propositions. The first is, that in so far as we know aught concerning the Primary Planets, matter exists there in the same three normal conditions as we find it existing on the Earth, viz: in the solid, the liquid and the aëriform or gaseous states. These orbs have, as far as we know, atmospheres; and we discern floating about in these atmospheres clouds, clearly indicating that there is developed in them matter in a liquid state, so that the inference is that their physical constitution is in every respect similar to that of our own Earth. There is one important exception to this, however, which we are *certain* is manifested by one orb and which may characterize all the Secondary Planets. This exception occurs in the Moon. In the Moon we find matter in the form of air. The Moon has an atmosphere, though a small one. There are many doubts concerning an atmosphere in the Moon, but I think, however, that the phenomena which have been observed during Solar eclipses go to show that it has an atmosphere. Matter in the liquid form, however, does not exist on the Moon. There is no water in this Luminary and never has been any, a truth which we shall be able to establish in the course of the lecture. The mode in which we ascertain the absence of water in the Moon is very simple and accurate. It is as follows: As we can trace the Moon through all its phases, we may also trace the line of increasing or roaming light, which is the line of the beginning of morning or the close of evening, across every portion of its surface. Now if that light passed across an ocean or great lake or any collection of liquid, we would find, as is the case when our own ocean is the horizon, that it would be an even line unmarked by any ruggednesses, but on the contrary this line is rugged everywhere, arising from the shadows cast by irregularities in the ground across which it stretches. The Moon, indeed, has comparative flat places, such as those dark spots marked on the map, easily seen on the Moon's surface with a good telescope, but even there the ground is undulating and quite unlike any collection of water.

The second truth, however, is much more important and contains that to which, more especially this evening, I would solicit your attention.

The following fact appears to be universal. We discern it in all the planets which we have been able to examine. It is this: the surfaces of these orbs are broken and irregular, like the surface of the Earth. In other words we find there mountains, continents, oceans, great valleys and irregularities of every description which we find on the Earth. The Moon is an especial example of this. In most other planets mountains are discerned, and in some of them, such as Mars, we see even the division into continent and ocean. While acknowledging the importance of this fact, however, I do not deem that the simple discovery of what modes and disposition of land and water, of ocean and continent are manifested by the surface of any of these globes, is that which ought most to attract us during the examination; we propose, nay, we cannot regard these modifications aright, as we find them in Mars, Venus, and the Moon, unless the grand and singular fact be retained in the memory, that the phenomenon is a Cosmical and Universal one; and that whatever the cause which has upheaved the surface of these orbs, it has acted throughout all the domain of the Planetary System and left its mark on the face of every body yet explored by the Telescope.

Regarding the subject, then, in this its real generality, we cannot avoid the conclusion that if the Science of Geology shall ever succeed in discerning the source of the influence that has thus diffused its results so widely, we ought through this its grand generalization to explain satisfactorily not merely the form and phenomena of upheavals as they are developed on the Earth, but likewise all similar aspects recognizable among our Companion Planets; or if expectation so high is too ambitious for the present condition of Geological Science to account it hopeful, there is still in the truths revealed by these foreign bodies, much wherewithal we may correct premature or special conclusions, and by whose aid we may avoid the hazard of accepting as an universal law what is a simple result of circumstances that have no universality but belong rather to the constitution and specialty of the particular orb we examine.

The great value of our looking at the Moon and these other bodies in this point of view is that it will enable us to relieve our theories concerning the structure of the Earth from all mere specialty. It is with this view then, and not merely to gratify curiosity by an inspection of isolated wonders, that to night I solicit you to review the appearance of the Moon—a planet which of all others is most within our reach and connected with which we find almost every conceivable facility for clear and little-interrupted inspection.

The Moon, of all other bodies, is situated so that we can obtain the most favorable view of it with the Telescope. In the first place the entire absence of water causes the absence of clouds, hence the surface is never tinged with obscurity, or if tinged at all, only obscured in consequence of the mist floating in our own atmosphere. All the

other planets are more or less obscured by clouds floating in their atmospheres. Venus, for instance, although so near us, has such a heavy atmosphere constantly surcharged with clouds that our knowledge of the orb is doubtful; while Mars, although much farther from the Earth, is, owing to the variety of its atmosphere and its freedom from clouds, seen with singular distinctness. The Moon, as before remarked, having none of these obstructions, appears clear and distinct. Beside, it is comparatively very near the Earth—being only 240,000 miles from us, a distance which, astronomically speaking, is but a mere unit. Now taking into account what the Telescope can do, the Moon is brought very near us. A nine-inch Telescope, with a magnifying power of a thousand times which I for some time used, brought, as you can readily calculate, the orb within two hundred and forty miles of me. A Telescope with a magnifying power of three thousand times would bring it within eighty miles, and by applying a power of ten thousand, which might be done under favorable circumstances, this Luminary would be brought within the small distance of *twenty-four miles!* The audience must not compare observing the Moon at this distance of twenty-four miles with viewing an object located on the Earth, at the same distance, for the view of the Earthly object would be obstructed by the lowest and densest portion of our atmosphere; but it should be compared with the view we would have of an object situated directly above us at the hight of twenty four miles, when the vision would be much less affected by the atmosphere intervening, as it would be of the the clearest and best quality. I hope the audience will not take such a view of the matter as a gentleman did who on hearing me state that we could go within eighty miles of the Moon, waited on me afterward in troubled wonder, asking why we did not skip over the intervening space and go out to it altogether? (Laughter.)

Such are the circumstances with which we approach the examination of the Moon. In possession of these facilities, then, and with the foregoing object in view, let us examine with attention the up-heavals which this globe [the Moon] presents: and we find them divided into three distinct classes or orders.

I will just mention shortly, before proceeding to the description of these mountains, the means by which we ascertain their character and elevation. This is effected by measuring the shadows cast by them upon the Moon's surface. To illustrate: You observe that this pitcher casts a shadow of a certain length. Now as I raise this light the shadow grows less and less, till at length you perceive that, as the light arrives exactly over the object, it casts no shadow at all, and as the light continues to pass on the shadow begins to appear on the opposite side of the pitcher, and it continues to grow longer and longer as the light descends. We observe the relative positions of the Sun and the Earth. We mark the extremities of the long deep shadows cast by those elevations on the Moon's surface, and we find that as the Sun mounts higher and higher in the heavens, these shadows gradually recede toward the bases of the mountains: and when the Sun arrives at the zenith the shadows entirely disappear; but by-and-by, as our majestic Luminary sinks to his bed in the West, the shadows come creeping out on the opposite side of the elevations, and we, by watching thus their movements, are enabled to ascertain with mathematical accuracy the character and hight of these Lunar mountains. There is no exaggeration in respect to our ability to measure hights and distances on the Moon. The shadows on the Moon are not like shadows on the Earth. They are black as midnight, and as clearly defined as form can be. Thus are these results reliable, and in truth we are at present better acquainted with the structure of one side of the Moon than with any hemisphere of our own globe.

There are three classes of Lunar mountains.—The first class consists of isolated, separate, distinct mountains of a very curious character. The distinguishing characteristic of these mountains is this: they start up from a plain quite suddenly.—On the Earth, it is well known that mountains generally go in ranges or groups, but we find these isolated Lunar mountains standing up entirely apart—never having been connected with any range.—Here is one [the lecturer here pointed to a splendid telescopic map of the Moon] named Pico, which is 9,000 feet high. This mountain has the form of an immense sugar-loaf; and if the audience can imagine a fairly-proportioned sugar-loaf 9,000 feet in hight, and themselves situated above it so as to be able to look down upon its apex, they will have an approximate idea of the appearance of Pico. There are many other mountains of a similar description scattered over the Moon's surface, and these mountains not only stand apart from each other, but, what is still more remarkable, the plains on which they stand are but *slightly disturbed.* How singular, then, the influence that shot these mountains up 9,000 feet and yet scarcely disturbed the plain in their immediate neighborhood.

The second class of Lunar elevations consists of mountain ranges. Now this is the principal feature of the mountains upon Earth. They are rarely found associated in any other manner than in vast ranges. This phenomenon is also found in the Moon, but there it is the *exception;* only two principal ranges are found and these appear to have been originally one range.

One is called the Appenines. It is so well seen that just as the line of light is passing through the Moon you will think it is, generally speaking, a crack in its surface, but a telescope of ordinary power will at once manifest it to be a range of mountains. Now the Lunar Appenines may be compared with the loftiest ranges of mountains upon Earth. It is 18,000 feet high, and there is another range still higher—rising 25,000 feet above its base. In this feature, then, the Moon corresponds with the Earth, but with this difference.—What is the *rule* on the Earth is the *exception* on the Moon.

There is, however, another very remarkable feature in which these ranges in the Moon correspond with Terrestial ranges. We find that on one side the mountains are quite steep, descending precipitously, while on the other side they slope away through an extensive highland. Now this very remarkable law holds also with respect to our Terrestial ranges. It is not universal but is so general that some of our Geologists have assumed it as mainly indicative of the cause that has up-heaved our mountains. The Himmalaya mountains present this feature most strikingly. On the South side they are bold and precipitous, while on the North they shelve gradually away, extending in picturesque grandeur over many a mile of mingled mountain, valley, gentle declivity and rolling plain, till at last they slope gently down and are lost in the level earth. So, too, the Andes exhibit this feature. It is a fact too remarkable to be considered accidental, and assuredly the cause which produced it upon the earth Earth must be similar in Nature to what evolved it in the Moon. Now our physical Geographers have usually been disposed to attribute the Terrestial phenomenon to the action of great floods or currents of water originating in different ways. And it seems no inadequate illustration of the ben-

efit which Astronomical observations might bestow upon Geology that the Moon negatives this explanation at once, for on this orb, as we have said, no liquid exists and has never been.

But the prevalent form of elevation belongs to neither class. At least two-fifths of the surface of our Luminary are studded with profound caverns penetrating its body, and generally engirt at the top by a great wall of rock which is surmounted or crowned by lofty peaks. These caverns, or, as they have been termed, *craters*, vary in diameter from fifty to sixty miles to the smallest space visible, probably one hundred and fifty feet; and the numbers increase as the distance diminishes, so that the multitute of the small ones passes enumeration.

In order to impress upon you what these objects are let us pay a visit to one of them, say the crater of Tycho. As we approach the crater we will find a very rough country. Our first glance would be arrested by a wall of solid rock appearing in the horizon stretching fifty miles away. As we approach we will find this wall sloping up to the hight of about 3,000 feet. Suppose we ascend. What do we expect to see on the other side—a slope? On the contrary, when we arrive at the top, we find ourselves on the brink of a precipice that in one leap goes down 13,000 feet! Then we discover below that enormous depth some similar ranges of mountains, lying like terraces and stretching round the base of the wall, and a little onward beyond these lies the bottom of the chasm which is 17,000 feet from where we stand. The diameter of the cavern is about fifty-five miles. If a person were standing down in its center he would see on every side, at a distance of twenty-five miles, an appalling precipice rising up 17,000 feet—2,000 feet higher than Mont Blanc. If there are any inhabitants there they must have some means of locomotion with which we are unacquainted. (Laughter and applause.)

Such then is Tycho, and precisely of this kind are all the craters in the Moon. Many of them are not so deep, some of them are deeper. Some in the southern part of the Moon are said to be so deep that we can never see the bottom. Whether this be so or not there are several 3,000 feet in diameter and as deep as Tycho.

Now it is evident on the very first glance that even our *largest* volcanic craters are not to be compared with these caverns of the Moon. The largest we have any knowledge of is in the South Sea Islands, but that is comparatively small and is situated at the top of a mountain. In order to discern aught similar upon the Earth, then, we must look to larger displays of the disrupting energy.

[The Lecturer here drew a diagram of a group of mountains among the Alps, exhibiting the circular formation but differing from Lunar Craters in two points. In the first place the range is broken by gaps; and secondly, the interior is not a pit, but, on the contrary, rather higher than the external surface of the Earth. He showed then how these might be explained by the presence of the meteorological agents—rain, frost, wind, etc.—on the Earth, which are not present in the Moon: and interpreting them by this principle it seemed that the older of our terrestial mountain formations rendered it likely that the crater form did, in the earlier epochs of the Earth's geological history, prevail likewise here.]

May it not then be that the Moon is simply in a comparatively early epoch of its developement? That, as the Nebular hypothesis would seem to establish, the Lunar globe is younger than the Earth; and that with regard to it, also, a time may come when the upheaving cause will manifest itself principally,—as now in the Earth—by upheaving ranges and groups of mountains instead of craters? This is probably all that we can derive from a view of this portion of the subject.

To proceed with our subject, can we form any idea regarding the nature of the power which could produce craters like Tycho? There is a feature connected with this crater which, in this respect, is of high importance. I mean those broad bands which issue from it and go across the surface of the Moon even to the distance, in one case at least, of 1,700 miles. [The Lecturer here went through a minute investigation of the characteristics of these bands, chiefly by means of diagrams on the blackboard, and elaborate paintings, which we regret we cannot give. He seemed to render it probable that, like our own trap-dykes, these bands consist of matter which must have come up from the interior of the Moon's mass through cracks in its solid crust. Now as these cracks must have been formed by the convulsion which produced Tycho, this convulsion, then, must have been sudden as well as most violent, at once producing the cavern itself and cracking the Moon in the manner in which we see it. The phenonema here indeed cannot be reconciled to any gradual operation or the action of any force long continued. It must have been as sharp as violent; instantaneous after the manner of an explosion. The imagination, habituated to the comparative quiet of our time, cannot easily reach the conception of a convulsion like this. Let my audience not discredit or doubt the speculation because of the fancied oddness or the gigantic character of the force whose action it presumes. So far from being impossible, the like of it, in part at least, has passed during the progress of time in almost every region of our globe. It is clear and perfectly indisputable, that when our own granitic ranges were pushed from the Earth's interior they bore up along with them many miles of rock of vast thickness that once lay quiet at the bottom of the ocean, and over which shell-fish crept, that are now entombed within their layers. Such convulsions were indeed often slow, and may have have occupied ages in their progress of completion, for the rocks that were disturbed are frequently little confused, lying around the central granitic mass as a graceful robe; but go with me to the Alps, or even to our own English Cumberland, or North Wales, and I could show you masses above masses which, when they were formed, lay as flat and even as the surface of that floor, not only turned from their repose and tilted upward in the air, but, by the violence of the action that disturbed them, rolled over each other in confused heaps, presenting for miles together to the puzzled explorer the aspect of a crumpled and crushed sheet of paper. Yes! *there*, indeed, has been power, immeasurable, scarce even conceivable; but the giant Earthquake has an arm capable of all this work. (Great applause.)

I would now, ladies and gentlemen, for one moment digress from our course and inquire, if the force that formed Tycho was so great, what became of the rocks that it blew out of Tycho? A cavern of that kind, fifty-five miles in diameter, is not an infinitesimal thing which may be easily formed. What became of these rocks? The most ready answer is that they returned again to the surface of the Moon, just as matter thrown from the Craters of our Volcanoes returns again to the Earth. There are circumstances, however, I think, that will induce us to pause before we assert that this took place.

In the first place, the Moon being a small body does not exert much attractive power over a mass, therefore it would not take much force to drive away a body from the Moon altogether, and send it

flying about through space. If this matter did go back, where is it?—we certainly should see it if it was there. Therefore we may say it is probable that this matter did not go back to the Moon at all, but that the violence of the shock was sufficient to send it off to seek its own fortune through space. (Laughter and applause.) Then what became of it? It must be moving through space in strange orbits, in bodies of different magnitudes. The orbits of the planets are so regular that with them there is no chance for collision, but with these masses flying round through space there is no chance to escape collision, consequently it is to be expected that these masses would be continually coming in contact with the Earth. Thus may we account for the falling of Meteoric stones. This is not a strange phenomenon. At least two masses must fall to the Earth per day—taking into account all that have been observed to fall—a phenomenon sufficiently large to require some important cause.—Now, if this force had sent off this matter from the Moon, the Meteoric stones would not be difficult to explain.

There was a theory concerning this phenomenon called the "Chemical Theory," which, as far as I ever understood it, was this. "Suppose certain particles floating about in the atmosphere, then suppose particular forces should cause these particles to come in contact and unite, then particular stones would be the result." Now there are three difficulties attending this solution. First, it cannot be established "that such particles were floating about in the atmosphere." Secondly—It cannot be proved that "particular forces would cause them to unite;" and thirdly, it cannot be shown that "particular stones would result from their unition." (Laughter and applause.)

But let me return to our direct subject We have now collected sufficient indications to entitle us to adventure some generalization regarding the seat of the force whose results we have been examining; but it may be well in the first instance to cast a rapid glance at other craters than Tycho. And I would as another instance of this description of formation claim your attention for one moment to the crater Copernicus. This is one of the most beautiful craters on the Moon's surface. It is best seen at the full of the Moon. It seems as if studded with pearls—a most beautiful object lying in the midst of a beautiful pearly light. When this light is analyzed we find that it, too, consists of a multitude of bands shining like those around Tycho; but, unlike those first bands, they wind along through the valleys of the undulating countries, and seem more like our superficial streams of lava. This, however, is the most remarkable circumstance about Copernicus. Notwithstanding the violent effort necessary to produce it, the plain in its immediate neighborhood has been scarcely at all disturbed. This very memorable feature we remarked as connected with the isolated peak, and it is eminently characteristic of the whole class of minor craters. From this, truth of vast importance may be immediately inferred, viz: that the seat of the convulsion causing these craters cannot have been located deeply within the Moon's mass. A profound force, capable of producing such a crater, must, at the same time, have shattered a considerable portion of the Moon's surface. No theory, then, at all related to the prevailing conceptions of a *central force* can be applicable here. The aspects of the Moon are in this respect wholly contradictory of the idea of a central force; nay, a Geology formed upon the ground of the appearances in the Moon would not contain any notion of a central force. It seems to me, then, not unlikely that that department of existing Geological theory which is founded on the supposed action of central forces, or on supposed relationships between the crust of the planets and their so called molten interiors, will ultimately undergo great modification.

Another fact of great moment seems to be rendered probable by the Moon, namely, that in the course of time the upheaving energy has been becoming less convulsive, or that an epoch of comparative stability has been approaching that body. [The Lecturer showed, here, by aid of diagrams, how the relative ages of the different craters might be approximately ascertained. It seems that Tycho is the oldest formation, and that as the ages proceed, the craters appear to have originated in less and less violent actions. This great fact also seems established in the Earth.] He then continued:

Connected with this curious subject there is a more general contemplation, on which notice should in conclusion be bestowed. What is termed the argument or consideration of *Final Causes;* that is an attempt to view any portion of the known Creation as an indication of the original purpose of the Divinity has ever seemed to me one which the human faculties cannot now undertake; for I cannot persuade myself that all the fitnesses that we see, multiplex as they are, go to constitute the entire of that scheme which the Almighty, from the innate necessities of his own perfections, determined from the beginning. It is thus, as I think, that every scheme observed by man has within it much of mystery, or, what is the same thing, points not accounted for, just because these touch on remoter forms of being and mightier plans. But though it is denied us to speak dogmatically in regard of anything that we can see of the ultimate or primary purposes of God; in no part of creation, great or small, when understood aright is want of harmony descried, or that adaptation which tells of the exquisiteness of the work of an Omniscient and Omnipotent Creator. In reference to the scenes over which to-night we have traveled, we have found the long existence of eras of unsettlement and commotion, and a promise of a period of repose. Sympathizing with inorganic Nature, and toiling along with her, the vital energies have accordingly all along accommodated their products to these vast transitions. Passing by the primal ages, it seems clear that only when Nature's actions became so ordered that in the main they could foresee by ordinary prudence, was the Earth a fitting habitation for a being gifted with pure reason and will, and thereby cut loose from the safeguard of pure instinct.

I think the audience will understand this idea.—We can imagine creatures of instinct fitted to live in any state in the world. We know that the instincts of animals forewarn them of dangers which man with all his boasted reason cannot foresee. These beings of instinct can in many cases foresee some of the great calamities of Nature, such as earthquakes, volcanic eruptions, etc. The beings of reason could not understand the approach of these dangers. A world may be adapted to the abode of beings under the control of instinct which would not be at all adapted to the abode of those compelled to trust for safety to their reason alone. We know that there are some portions of the Earth unfitted at the present time for the habitation of Man—regions where the erections of civilization for years are overthrown in an hour; consequently, in those portions of the Earth the inhabitants are, for the most part, semi-barbarous. This may account for the comparatively recent appearance of Man in the world. Long before his appearance, we find the Globe teeming with races of beings, but all of them of an

inferior creation to Man—beings of instinct. Passing, then, I say, by the primal ages, it seems clear that only when Nature's actions became so ordered that in the main they could foresee by ordinary prudence, was the Earth a fitting habitation for a being gifted with pure reason and will, and thereby cut loose from the safeguards of pure instinct. Man then appeared : made his epoch. The destructive forces still prevailed, but not farther than, as a whole, he could combat with ; and he has fought with them and the sterile Earth, and achieved a creation of his own. The fitness of such a being for such a state is manifested by his triumphs; for while the earthquake has diminished its subterranean thunder, the marsh has ceased to exhale its poison, and culture has driven back the terrors of the once eteroal snows. And science shall proceed in unison with the change of great Nature, until an epoch shall be achieved when, external foes all vanquished, our race shall see the Universe everywhere as a friend and nowhere as a foe; when that repose shall be found fitted for contemplation, flourishing mostly in repose—contemplations which are the object of the yet least developed faculties of our Human Nature—those which point to the august pleasure of Immortality and God. (Great applause.)

LECTURE VII.

Constitution of the SUN....Discovery of spots on his surface and the rotation of the orb....Nature of these spots....The solar atmosphere....Inquiry and speculation concerning the cause of the spots....Striking similitude with terrestrial atmospheric commotions or storms....Probable existence of other changes in the Sun....Conclusion of the Course.

LADIES AND GENTLEMEN: On the last evening, I opened to you in the cursory manner which alone is in accordance with a course so brief as this, the question of the peculiar constitution of the several planets which, with the Earth, roll round the Sun. In the course of that lecture we looked especially at the Moon, and I think we saw cause to modify, somewhat, the conclusion usually drawn by geologists from the several modes of its development in Earth, respecting the ultimate character of those grand causes that have so universally upheaved the surface of all these planets. The conclusion we would be disposed to draw from first sight is, that this cause is a central one; but I think we showed that this could not be the case.

Those changes, however, to which I then alluded, are merely a few scenes in the history of the planets. Now, what are these in relation to our whole System? Incidents themselves in the condensation of the Sun, just as their internal geological epochs are incidents in the course of their own, how utterly they shrivel and vanish from sight, when we turn to that Orb himself whose history, in very truth, the history of our System solely is. I think I stated, on a previous evening, the fact that the diameter of the Sun is so enormous when compared with the other bodies in our system, that if the Sun be represented by a globe two feet in diameter, Jupiter would be represented by a ball no larger than an orange, and our own Earth by a speck only.

The phenomena that first led to some knowledge of the constitution of this vast Orb, are those curious spots that appear and disappear so frequently on his surface, and which by their regular progression across his disc, revealed to their first discoverer, Galileo, the remarkable fact that the Sun rotates on his axis like the planets, carrying the spots along with him.

We find, on examining the Sun with a good Telescope, that rarely a day occurs in which his surface is not marked by dark spots which frequently appear with great suddenness, and disappear with exceeding rapidity. This was one of the earliest discoveries of Galileo. On looking at them, he found they were not fixed upon the Sun's surface, but were continually changing their places. Now, on endeavoring to ascertain what the cause of this change was, he discovered that all the spots moved in one direction, and also in definite curves. He found that all these phenomena might be explained by the supposition that the Sun is an immense globe turning on its axis. He detected from this, also, something like an approximation to the time required by the Sun to perform one revolution on its axis. He estimated the period to be about twenty five days.

Before another step was taken in this inquiry, very many years elapsed; nor was the light they cast on the nature of the substance and constitution of the Sun recognized until the times of Dr. Alexander Wilson and Sir William Herschel,—the former of these eminent men, earliest beyond a doubt, establishing the cardinal act in this high inquiry Some remarkable features that invariably characterize a Solar spot, had attracted his attention and accident as he modestly said—but of course one of those accidents that can be taken advantage of by Genius, enabled him through them to read the whole significance of the phenomena. The features in question are these.

The spots that attracted Dr. Wilson's attention—a man whom I am proud to name as my almost immediate predecessor—were as follows: In 1769, a large spot broke out in the middle of the Sun which attracted the attention of all the Astronomers of that time. He noticed that this spot was moving onward, and that as it passed across the surface of the Sun, a very singular series of changes occurrred. When in the Sun's center, the spot presented the following phenomena, just as in the fact do all the spots on the Sun's surface: He found that the center was the only portion of the spot that was quite dark. Around the center he found an edging, which he called the Umbra. As the spot went forward, the Umbra diminished; and when it went on still farther the Umbra disappeared, and nothing but the edging on the side opposite himself was visible. [Here the Lecturer referred to a couple of large diagrams, representing the various phenomena presented by these Solar spots.]

In explanation of these phenomena, Wilson formed a very ingenious theory. He said, if this large spot lasts long enough for the Sun to bring it round again, I shall see the following phenomena: As it comes round, I shall see, first, the opposite edging, and as it comes on down to the center of the Sun, I shall see the spot with its black center surrounded with the edgings. Well, the spot did continue long enough for Wilson to make the desired observations, and he found his predictions in every respect verified. [The Lecturer here exhibited, by means of a common globe, the course of reasoning pursued by Wilson in the formation of his theory.]

It followed at once, from Wilson's capital discovery, that our magnificent Luminary is not a chaotic conflagration, but a body having a definite organization, revealed in so far by the aspects of these openings; and to the solution of the momentous question as to what this organization is, the singular powers of the elder Herschel came quickly in aid of the efforts of his friend. With both of these illustrious men, it early became a fixed belief that the surface thus broken by chasms must be aërial—or some elastic gaseous fluid like our atmosphere; for notwithstanding the magnitude of these spots, sometimes reaching even 50,000 miles in diameter—they open and close with a rapidity next to marvelous, often surpassing the rate of 1,000 miles a day.

Nowhere, perhaps, in all the annals of discovery, is there aught that more stirs thought or raises more strange questions than this! Let us see into what it summons us to inquire.

I. The play of sudden, tremendous and evanescent forces, either connected with the solid body of the Sun or generated within his atmosphere, has become an absolute fact; now where and what are these? But in the first place, and passing beyond the spots, let us briefly review the whole known phenomena.

There appears no rest whatever in the atmosphere of the Sun. Over all its surface, waves of light seem to dart incessantly, assuming the most varied aspects. The bright part, as Herschel early discerned, is full of inequalities, showing first, parts more brilliant than the rest, sometimes round, sometimes elongated—mountain billows in that light-ocean. Then there are large dim spots extending over immense tracts, but showing no dark center—constituting what Herschel termed *shallows*.

We find that these spots are not fixed, but are continually dashing along the center of the Sun. Now, when we come to the consideration of the spots themselves. we find them characterized by certain remarkable phenomena, which will enable us to ascertain their cause. A spot never appears twice in the same place; but although they are not confined to a point, they are confined to regions. They always appears in the Sun's torrid zone. We never find the spot breaking out beyond that belt. Then, again, on looking more minutely, we find the spots themselves have a motion—a motion besides that which the rotation of the Sun causes, and it is most peculiar. We find that the spots which appear North of the Sun's Equator, move slowly toward the North, till they get to the temperate regions, and then disappear. No instance has been known of spots formed in the North going South. Just so, spots of the South move toward the South temperate zone and disappear.

There is still another circumstance characterizing the mode in which they disappear. Sometimes they go on till they get to the Sun's temperate regions and then quietly die away. At other times, they do not disappear in this manner, but split up just as if they were exploded by some violent force. This phenomenon I had the good fortune once to witness. It is most remarkable. It has been compared to this: Suppose a person standing upon a frozen pond should take up a piece of ice and cast it from him. Now, this mass of ice would be broken into a vast number of fragments, which would be scattered over the surface of the pond. This is exactly the manner in which these spots appear to be dashed and scattered over the surface of the Sun.

I have now unfolded all the phenomena exhibited by the Solar spots, and we must now direct our endeavors to ascertain their explanation. (Applause.)

If, unappalled by the majesty of the orb on which they proceed, or by the magnitude of the forces causing them, we propose to ourselves under the consciousness of the all-prevalence of Law, to seek out something analogous in our own planet, we will find them nowhere save among the phenomena of the winds. But the analogy is everywhere most striking, and probably the most complex and imposing aspects of the surface of the Sun. In reference to the bright parts which we deem heapings up of the shining atmosphere, as well as to the shallows which with the brighter parts are spread over it, our attention is inevitably drawn to the great Barometic changes that take place on the surface of our globe. You are aware what a change in the Barometer really means. It is this: The Barometer tells you whether the column of air above you is growing lighter or not. If lighter, the Barometer rises—if heavier, it falls. Now, until comparatively lately, the theory with respect to the change of weight in the column of air above us, was this: It was attributed to changes in the interior of that column. It was supposed that the air composing it underwent alterations in temperature. But another theory has been propounded, viz. that the changes in the weight of the column are caused by alterations in its hight, the column not remaining at the same elevation, but that it is continually changing—undergoing vast undulations, rolling like mighty billows. Now, you will observe that if we were outside of the earth and the upper portion of our atmosphere were, like the Sun's, self-luminous, then these waves would cause by their various commotions, appearances similar to the spots seen on the surface of the Sun. If we are right, then, the significance of these remarkable phenomena is clear. They indicate the surging of the Solar aërial masses. They are in fact the visible markings of the Solar Barometers; and through these, one day, may come to Science a knowledge of how the winds roll there, and what are their grand periods.

This inquiry is the most difficult that the astronomer has to pursue. We cannot look at the Sun with the naked eye, and the telescope augments his light. On this account we are compelled, when viewing the Sun, to use dark glasses, which detracts very much from the accuracy of our observations. I confess that it has sometimes occurred to me, that we ought, before this, to have got at a means which would enable us to observe the Sun with much greater accuracy than we have heretofore been able to do. I refer to the Daguerreotype. You all understand what has been accomplished by this. Now, if by the aid of the Sun, we can produce the most exact likenesses of whatever object we choose, I do not see why we should not request the Sun to write down his own image. (Applause.) For myself, I cannot see the possibility of failure. It is quite common to mount the telescope upon machinery, so as to enable it to follow the movements of the heavens throughout the day. Now, if we could fit up the telescope with these Daguerrean plates and point it at the Sun, we could in one day get a sufficient number of images, that we might take to our closets and examine with our microscopes, to enable us to completely unfold the constitution of the Sun. (Applause.)

Let me ascend, however, to what is far more striking. I will here remark that I am sure I need not explain to my audience what a boon it was when the hurricanes of the Tropical Regions yielded up the secret of their cause. I believe the gentleman to whom the world is indebted for this discovery is a resident of this City. His name is—[we did not catch the name]. I see him in the audience. (Applause.) These hurricanes are whirlwinds. They do not owe their power to the velocity with which they are moving over the earth, but to the velocity of their rotation. These hurricanes, then, are revolving cylinders of air, hollow in the center. Suppose, now, one were outside the atmosphere of the earth and looking at one of these phenomena. How would it appear? A mere spot, exactly resembling those we observe upon the Sun. Generally, these cylinders are round. In passing over a regular country, they would be round and regular; but if passing over a rough country, hills and mountains, they would be round but somewhat irregular. Now the spots on the Sun are not exactly round. Therefore, if they are analogous to those of the earth, they show the aspect of the ground over which they pass. Now, observe the regions in which these hurricanes appear: always in the Tropical Seas. Those occurring north of the Equator, move toward the north; while that occurring south of the Equator always

move toward the South. Just so with those in the Sun.

The thought is, indeed, overwhelming, when from these hurricanes, ay, or from the devastating Typhoon, we pass to tornadoes apparently similar in the atmosphere of the Sun, by whose inconceivable motion an opening of 50,000 miles in diameter may be made, extending through the entire depth of that atmosphere, probably many thousand miles. And yet, is not the electric spark with which the child disports itself, a key to the rending of tropic thunder? Is not the power of life which sustains the smallest wild flower exactly that which infuses strength into the giant pine and causes it to evolve its mighty branches? Yes! To these stupendous laws which, as ministers of God, work at the deep root of things and cast up all these wondrous phantasms, no event is small, no accident unthought for; we dwell in a Universe where not a floweret fades unseen, where the very hairs of our heads are numbered! (Great applause.)

My audience will observe, however, that in so far as we have gone, we have not established anything to entitle us to say that these phenomena upon the Sun are the same as those I have represented upon the earth. We have observed strong analogies indeed, but we must show that the causes which produced these phenomena upon the earth may operate upon the Sun. Now, you will observe, in the first place, that I have drawn all these phenomena from the winds. Now can winds exist upon the Sun. What is the cause of winds? It is simply this: The atmosphere in different portions of our globe is unequally heated. If all parts were heated in the same degree, there would be no winds. One cause of the difference in heat on the Earth is the shining of the Sun. At the Torrid Zone, his rays are vertical, or nearly so, which renders his heat intense, while at the North and South his rays are very oblique; consequently the degree of heat in those regions is much less than it is in the Torrid Zone. Now, it is impossible that this cause should operate to produce winds in the Sun. There is another important cause, however, of winds in the Earth which may exist in the Sun, viz: a difference in materials. This difference is such that if the rays of the Sun should come down exactly the same on all parts of the Earth, the difference in the degrees of heat would be very great. Take, for instance, a case of the Sun shining on the sand and on the water. The sand on the margin of a river may be scorching hot, while the water is very cool. Now, where are the hot regions on the Sun, and where are the cold? Where is the Continent? Where is the Ocean? Now, this inference is within the range of Science. There is, however, a difficulty in carrying the explanation out. It is very probable that the phenomena of these hurricanes of ours are owing to the trade-winds. Now we cannot determine trade-winds in the body of the Sun. The question with respect to these lies open for farther observation.

Here, then, is another field of most engrossing speculation. This, even, that these surgings in the Solar atmosphere are the key by which future generations may unlock his character, shrouded though now he is in his noble and impenetrable splendor! This is the wing on which Intellect may pass where vision never can, and explore the hidden Orb, examine his continents and oceans, his plains and majestic mountains. And why incredible? Why should not Intellect pass, as of yore, where the feeble eye can never reach? For note the history of this very discovery! Once an acorn, already it has become a young oak with many branches, and nought shall hinder it to stretch yet farther toward the skies! When Galileo through his rude Telescope first noted a few dark specks on the disc of the burning Sun, that globe of fire, as people thought, men were all struck in amaze, and because of their amaze almost would have stoned him. Time rolled by, during which some thought that the spots were the ashes of the burned Sun; others that they were the dark souls of the punished floating in fire. (Laughter.) A great man then analyzed the spots and determined their character. By degrees, and only by degrees, and by the efforts of separate thinkers, they have come to be considered as a class, and those laws sought to be discerned on which deeper questions certainly depend. Tell me not that Thought shall stop or the Human Intellect here be stayed. The mighty Avalanche grows among its native hights unseen by Man, silent and unknown for ages; but as its mass enlarges, though it be but by the fall of flake after flake of the downy snow, the moment of its freedom is surely approaching—the moment when, delivered from bondage by a stroke of sunlight, it shall thunder to the plain, and the mountains shall shake with the echoes of its powers! (Great applause.)

II.. Another subject remains still more stirring. If our views of the Sun are correct, he is distinguished from the planets that encircle him only by his phosphorescent robe. Now what is that phosphorescence? Is it peculiar, is it permanent?

Again we descend to our own planet, and our first thought leads us to the Auroras. Whatever their origin, they show the existence of causes in virtue of whose energy the upper strata of our atmosphere become self-luminous sometimes in a high degree, for in Northern regions our travelers have read by their brilliance. But the Aurora is not the only phenomenon which indicates the existence of a power in the matter of our globe to emit light.

You have all heard of these brilliant Auroral phenomena. It is supposed, that in a previous epoch of our globe, these phenomena were manifested in a much higher degree than now. On the Melville Islands we find plants which I should call ultra tropical. They are much too large to grow on the Earth now. These plants must have enjoyed an immense amount of heat and light. Whence could they derive these? They could not be derived from the Sun, while the axis of our Earth remains at the same inclination as now: and, of course, we have no reason to believe that it has ever been situated otherwise than at present.—Consequently, we must infer that our Earth did possess, at some former epoch, the power of emitting a sufficient amount of heat and light to sustain the growth of these plants. The existence of this illuminating power, although apparently in its debilitude, we discern also in appearances among the other orbs. Flashes like our Aurora are said to have been observed over the dark hemisphere of Venus and the obscure part of the Moon is believed to have been visited by similar phenomena; but the circumstance most remarkably corroborative of the mysterious truth to which these indications point is the appearance of our midnight Luminary during a total eclipse.

When the Moon is totally eclipsed, you are aware that it goes entirely into the Earth's shadow. No light comes to it, therefore, from the Sun. There may be some stray rays; but calculation shows us that they are not sufficient to cause any apparent diminution of the eclipse. Well, then, in what position ought the Moon to be, when totally eclipsed? She should disappear entirely, should be blotted out from the sky. But on the contrary, instead of being blotted out, she is perfectly visible in the sky, an immense bronze disc, and with the aid of a telescope, all her phases can be traced. Now, this

could not be, unless the Moon were sending out light herself.

From all these circumstances, there seems no tenable conclusion save this; that the matter both of Sun and planets is capable in certain circumstances, whose exact conditions are not known, of evolving the energy we term Light; and that the atmosphere of the Sun is at present under influences favorable to the high manifestations of a power which from the other orbs has not wholly departed. And thus forever is broken down that supposed distinction, which seemed to place our central luminary apart in space to an immeasurable extent from the humble worlds that roll around him.

It will naturally be expected, that if our theory be true, if the power to evolve light be subject to change, it may have left its impress on that farthest field of its energy—the wilderness of the Fixed Stars. Now, startling though it at first sight must appear, on all sides, there are here marks of change and of the modifications of light-giving power. The Stars have changed their colors. They have been described by their colors. Poets used to call Sirius the "Red Dog-Star:" Now it is the whitest star in the Heavens. The stars have also altered their quantities—they have diminished their magnitude without changing their place. Tycho, a Danish astronomer saw one night in the constellation Cassiopea, a most brilliant star which he had not previously noticed. He watched it for a year. It grew brighter and brighter until it became as light as Venus. After a year, it began to wane, and continued waning and waning, exhibiting the appearance of a dying conflagration. This is but a rapid instance of that change which is constantly going on among the stars.

Sir John Herschel, at the Cape of Good Hope, witnessed a similar phenomenon. He saw, on looking at the Star η Argus, it was brighter than laid down in the catalogues. It was originally a star between the second and third magnitudes. It went on increasing till it became not only a star of the first magnitude, but the third star in brightness in the whole skies, after which it began to wane. Herschel's theory was, that there are what might be called cosmical clouds floating about in space—that these clouds intervene between us and the stars, thus darkening them. This theory, however, is not generally received. Why, it is asked, do not these clouds dim other stars? Especially, with respect to this Star of Tycho, how could a cloud have rested before it, from the beginning of time, and just went away for a year and then returned again? I think we are bound to reject this explanation.

Deeper, far deeper among Nature's potencies must be the origin of these astonishing displays.—Doubtless they result from varied comminglings of the energies that produce light, and which, as we have seen, act far and near. And here as Time rolls on, these, like others, are ever weaving a devious web, their product, Light, must, as ages course, sparkle variously in every portion of their vast domain. And thus one other fanciful tradition disappears! No more is Light inherent in the Sun than in Tycho's vanished Star; and as with it and other orbs, a time may come when through the concert of all the powers of Nature, he may cease to be required to shine. And if even now he is only in one stage of this majestic mutation—if, as the Planets have rolled on and worked out their fates under his beams, he, the Vivifier, has been changing and yet must farther change—once more are we in presence of revolutions that seem illimitable—of progressions whose vista reaches to the very infinite—and we are but as points amid accumulating, superimposed immensities—flashes from the wheel of the Burning Car—creatures we know not what!

Oh what a world is this! Change rising above change, cycle growing out of cycle in majestic progression, each new one ever widening—like the circles that wreathe from a spark of flame, elongating as they ascend, finally to become lost in the empyrean! And if all that we see—if from Earth to Sun and from Sun to the Universal Star work—that wherein we the best behold images of Eternity, Immortality and God—if that is only a state or phase of a course of Being rolling onward evermore—what must be the Creator, the Preserver, the Guide of all. He at whose bidding these phantasms come from nothingness and again disappear, whose Name—amid all things—alone is EXISTENCE—I AM IN THAT I AM! The All-Encompasser: the All-Sustainer! He enwraps, He upholds all those gorgeous Heavens! Yea, unassisted, uncounseled, sustains he not unchanged and unchangeably forevermore, even the fabric of His own Awful Being! Reverentially before him—humbly grateful that in the course of this beneficent arrangement He has permitted such intimations of his glory to reach us—let us conclude in the rapt language of the Psalmist: How manifold, oh God, are thy works, by wisdom Thou hast made them all!

POPULAR LECTURES

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BY DIONYSIUS LARDNER,

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LECTURE I....THE PLURALITY OF WORLDS.

Contemplation of the Firmament—Reflections thereby suggested—Limited Powers of the Telescope—What it can do for us—Its effect on the Appearances of the Planets—Are the Planets Inhabited?—Plan of the Solar System—Uniform Supply of Light and Warmth—Expedient for Securing it—Different Distances of the Planets do not necessarily infer different Temperatures, nor different Degrees of Light—Admirable Adaptation of the Rotation of the Earth to the Organization of its Inhabitants—Minor and Major Planets—Short Days on the latter—The Seasons—Similar Arrangement on the Planets—The Atmosphere—Many Uses of the Atmosphere—Clouds—Rain, Hail, and Snow—Mountains on the Planets—Land and Water—Weights of Bodies on the Planets—Appearances of the Sun, &c. &c.

LECTURE II.....THE SUN.

The Most Interesting Object in the Firmament—Its Distance—How Measured—Its Magnitude—How Ascertained—Its Bulk and Weight—Form—Time of Rotation—Spots—Its Physical Constitution—Luminous Coating—Temperature—Luminous Matter, &c. &c.

LECTURE III.....ECLIPSES.

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Form and Arrangement of the Mass of Visible Stars—Sir W. Herschel's Analysis of the Heavens—The Milky Way—The vast Numbers of Stars in it—Nebulæ and Clusters—Great Nebula in Orion—Megallanic Clouds—Planetary Nebulæ—Vast Number of Nebulæ—Herschel's Catalogue—Structure of the Universe—Laplace's Nebular Hypothesis—Examination of its moral Tendency.

LECTURE LVI....THE STEAM-ENGINE.

(First Lecture.)

The Steam-Engine a Subject of Popular Interest—Effects of Steam—Great Power of Steam—Mechanical Properties of Fluids—Elasticity of Gases—Effects of Heat—Savery's Engine—Boilers and their Append-

ages—Working Apparatus—Mode of Operation—Defects of Savery's Engine—Newcomen and Cawley's Patent—Accidental Discovery of Condensation by Injection—Potter's Invention of the Method of Working the Valves—His Contrivance improved by the Substitution of the Plug-Frame.

LECTURE LVII ....THE STEAM-ENGINE.

(Second Lecture.)

Mechanical Force of Steam—Watt finds Condensation in the Cylinder incompatible with a due Economy of Fuel—Conceives the notion of Condensing out of the Cylinder—Invents the Air-Pump—Substitutes Steam Pressure for Atmospheric Pressure—Invents the Steam Case or Jacket—His Models—Difficulties of bringing the Improved Engine into Use—Watt employed by Roebuck—His Partnership—His first Patent—His Single-Acting Engine—Discovery of the Expansive Action of Steam—Extension of the Steam-Engine to Manufactures—Attempts of Papin, Savery, Hull, Champion, Stewart, and Wasbrough—Watt's Second Patent—Sun-and-Planet Wheels—Valves of Double-Acting Engine.

LECTURE LVIII....THE STEAM-ENGINE.

(Third Lecture.)

Methods of Connecting the Piston-Rod and Beam in the Double-Acting Engine—Rack and Sector—Parallel Motion—Connection of Piston-Rod and Beam—Connecting-Rod and Crank—Fly-Wheel—Shuttle-Valve—Governor—Construction and Operation of the Double-Acting Engine—Eccentric—Cocks and Valves—Single-Clack Valves—Double-Clack Valves—Conical Valves—Slide Valves—Murray's Slides—The D Valves—Seaward's Slides—Cocks—Pistons—Cartwright's Engine.

LECTURE LIX.....THE STEAM-ENGINE.

(Fourth Lecture.)

Analysis of Coal—Process of Combustion—Heat evolved in it—Form and Structure of Boiler—Wagon-Boiler—Furnace—Method of Feeding it—Combustion of Gas in Flues—Williams's Patent for Method of Consuming unburned Gases—Construction of Grate and Ash-Pit—Magnitude of Heating Surface of Boiler—Steam-Space and Water-Space in Boiler—Position of Flues—Method of Feeding Boiler—Method of Indicating the Level of Water in Boiler—Lever Gauges—Self-Regulating Feeders—Steam-Gauge—Barometer-Gauge—Watt's Invention of the Indicator—Counter—Safety-Valve—Fusible Plugs—Self-Regulating Damper—Brunton's Self-Regulating Furnace—Gross and Useful Effect of an Engine—Horse-Power of Steam-Engines—Table exhibiting the Mechanical Power of Water converted into Steam at various Pressures—Evaporation Proportional to Horse-Power—Sources of Loss of Power—Absence of good Practical Rules for Power—Common Rules followed by Engine-Makers—Duty distinguished from Power—Duty of Boilers—Proportion of Stroke to Diameter of Cylinder—Duty of Engines.

LECTURE LX.....THE STEAM-ENGINE.

(Fifth Lecture.)

Railways—Effects of Railway Transport—History of the Locomotive Engine—Construction of Locomotive Engine by Blinkinsop—Messrs. Chapman's Contrivance—Walking Engine—Mr. Stephenson's Engines at Killingworth—Liverpool and Manchester Railway—Experimental Trial of the "Rocket," "Sanspareil," and "Novelty"—Method of Subdividing the Flue into Tubes—Progressive Improvement of Locomotive Engines—Adoption of Brass Tubes—Detailed Description of the most Improved Locomotive Engines—Power of Locomotive Engines—Position of the Eccentrics—Pressure of Steam in the Boiler—Dr. Lardner's Experiments in 1838—Resistance to Railway Trains—Dr. Lardner's Experiments on the Great Western Railway—Experiments on Resistance—Restrictions on Gradients—Compensating Effect of Gradients—Experiment with the "Hecla"—Disposition of Gradients should be Uniform—Methods of surmounting Steep Inclinations.

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